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SOIL CONDITIONS

Mission Bay
San Francisco

September 1986

San Francisco Department of City Planning

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Soils Conditions
Mission Bay
San Francisco

Prepared for:
The Department of City Planning
San Francisco, California

Prepared by or in consultation with:
Dames & Moore
Daniel Solomon & Associates
Shapiro, Okino, Hom & Associates
EDAW, Inc.
Williams & Burrows
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EQE

September 1986

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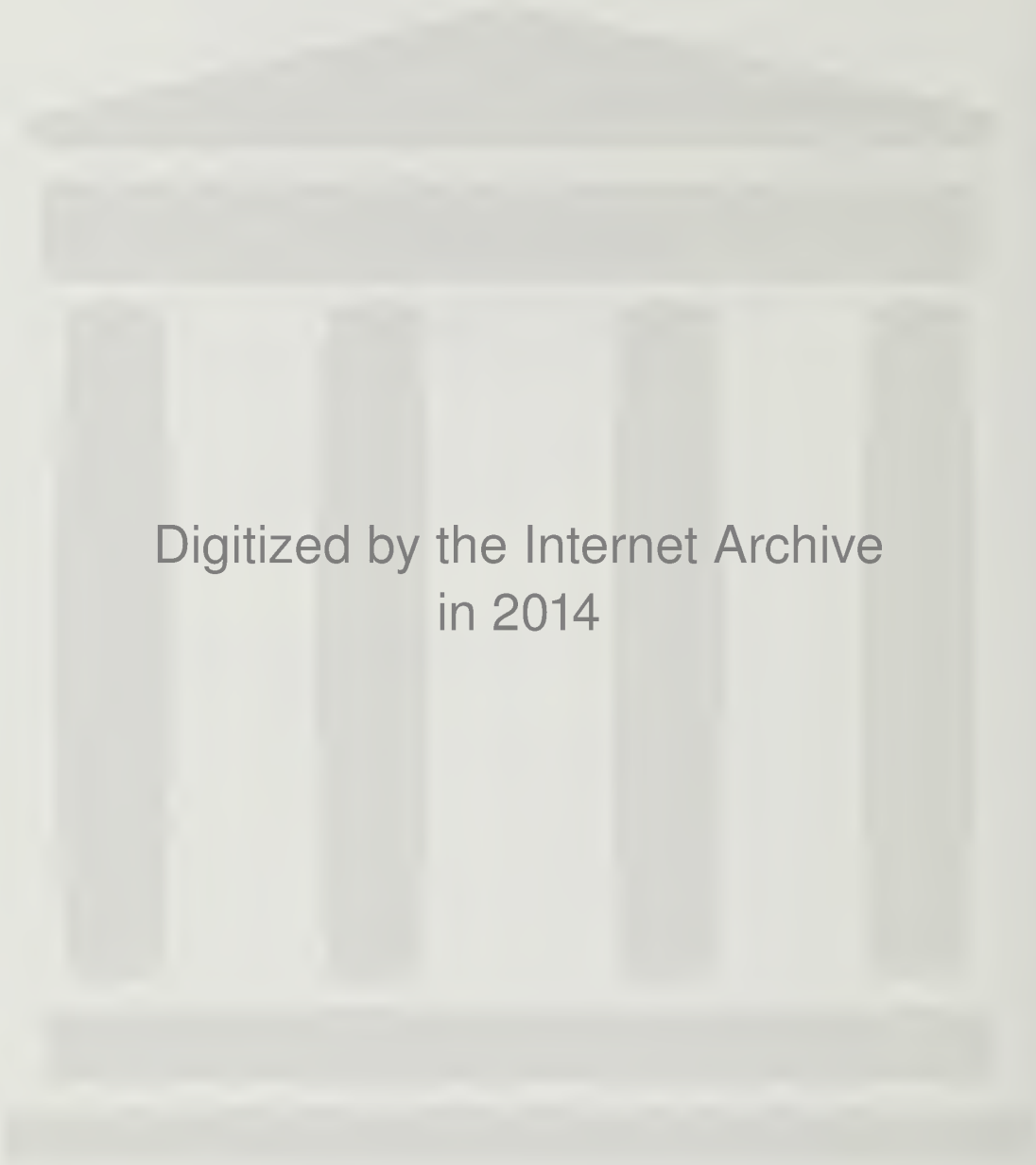

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1.0 INTRODUCTION AND SUMMARY

Preliminary investigations of soils conditions in Mission Bay have been undertaken beginning in 1982 and as recently as September 1986. The basic questions being addressed were:

1) what are the soils conditions on site, as they may affect development;

2) do soils conditions dictate the location or scale of residential development/ and construction types of residential buildings on the site and

3) if so, are there construction cost differences across the site that further constrain location of housing.

The land use most likely to be adversely affected by construction costs is housing, especially affordable housing. Therefore, recent soils investigations focussed particularly on examining the implications of soils conditions for housing location and construction. It is assumed that other uses, such as office and R&D will be developed in a manner feasible for market rate leasing or sales.

This site is expected to provide for 7500 or more new dwelling units on approximately 80-100 acres; other uses are planned for the remaining acreage. To achieve this housing program, dwelling units must be developed north of China Basin Channel at 120 dwelling units per acre ("DU/AC") average and at 75-80 DU/AC average south of the channel.

The Mayor's letter of October, 1984 to Santa Fe Pacific Realty Corporation stated that thirty percent (30%) of the new Mission Bay housing units should be affordable (below market rate, possibly subsidized). Mission Bay Objectives & Policies (November 1985) call for the even distribution of these affordable units throughout the site, amongst the market rate housing. This study has been prepared to determine the impact that soils conditions have upon economic construction of buildings that achieve the necessary densities, with 30% affordable units, and in the expected distribution on the site.

This study draws on several documents about Mission Bay soils. These documents are listed in Appendix A of this study. Also a series of recent memos that summarize preliminary conclusions are provided in full in Appendix B of this study.

Summary

Site soils conditions are one influence on the Mission Bay master planning process. There are several different generalized soils zones on the site, having varying settlement expectations and therefore varying implications for construction. On approximately one half of the site, buildings over two stories will require pile foundations. The construction costs associated with these more expensive foundations will adversely affect the financial feasibility of constructing affordable housing on the site. All else being equal, affordable housing should not be planned on the poorer soils on the site.

2.0 EXISTING CONDITIONS

The 300-acre site is located in what formerly was known as Mission Bay, a large shallow bay inlet. Most of it has now been filled with heterogeneous fill soils at the surface. This is underlain in sequence by sedimentary deposits of various strengths, the weakest and thickest member of which is bay mud and with bedrock. The groundwater elevation is slightly higher than the mean water level in nearby San Francisco Bay (mean sea

level). The groundwater is first encountered at depths of three to nine feet below the ground surface. These conditions vary across the site and substantially in areas being considered for housing.

During the Mission Bay planning process to date, the areas of the site that could be appropriate for housing, based on land use, urban design and programmatic criteria have been identified. These areas are shown in Figure 1. In shading is the area where housing development is being considered; in outline form, this is repeated on each following figure showing subsurface conditions.

The physical conditions of greatest importance are the thickness of the fills, thickness of bay mud and depth to bedrock. The first two factors and the time of placement of the fills determine how much compression of mud occurs. This compression is called settlement. Following are Figures 2, 3 and 4 that illustrate the three individual conditions: bay mud, bay thickness and depth to bedrock.

2.1 Settlement

Settlement affects construction in two ways: the total settlement that will occur in the area (areal settlement) and the differential settlement versus distance, i.e., over what distance does the areal settlement vary in amounts that affect housing or infrastructure engineering performance. The vertical and horizontal extent of areal and differential settlement influence choices about the appropriate housing construction techniques. With limited areal settlement (two inches or less), low rise buildings can be built on compensating or raft foundations at significantly less cost than pile foundations; for these one or two story buildings, the building settlements will not be substantially different in amount or rate than the settlement of the surrounding sidewalk, landscape, utilities or streets. Pile foundations are not necessary in areas of limited settlement except if seismic safety requirements dictate, and/or there are buildings over two stories without basements and for all buildings over five stories. (See Mission Bay Seismic Safety Study, September, 1986)

In zones with significant areal settlement (6 or more inches), pile foundations will probably be required for all buildings to avoid adverse settlement behavior and to improve seismic safety. Pile foundations in these areas are expected to exceed 100 feet in length. Substantial cost per unit for construction is likely.

In addition to variations in areal settlements, differential settlements are influenced by other factors including old dock height fills (shown in Figure 6) and the location of earlier building foundations, particularly pilings.

Areas of the site can be prepared for development in order to reduce settlement through the use of drainage wicks and surcharging. It does not appear, however, that wick drains offer any substantial cost-saving opportunities on this site since they reduce but do not eliminate future settlement nor preclude the need for piles for all buildings. (See April 29, 1986 memo: "Preliminary Study of Drainage Wicks vs. Pile Foundations at Mission Bay".)

Figure 5 is a composite of these several soil conditions which yields a map of generalized soil zones determined by depth of bay mud, bedrock depth and anticipated settlement. Each zone has compound characteristics which are described below.

Zone A: This area has the shallowest depth to bedrock and mud depth (both are less than 90 ft.). It is expected to sustain the least areal settlement and to not

require pile foundations for buildings of 1-2 stories or buildings up to five stories with basements or depressed garages. Moderate density midrise buildings 6-8 stories or higher will still require piles in most areas.

Zone B: The small areas of Zone B on the site are defined by Bay mud of less than 60 ft. depth and anticipated settlement of less than two inches over the next thirty years. Pile foundations would probably not be required for buildings with basements or depressed garages in this zone except for moderate density midrise buildings 6-8 stories or higher.

Zone C: In these limited areas between 2-6 inches of areal settlement is expected with moderate bay mud depths. Pile foundations are more likely to be required.

Zone D: This area has fairly deep bay mud and between 2-6 inches of anticipated areal settlement over the next thirty (30) years. Pile foundations may be required throughout this zone; certainly, they will be required for buildings over 5 stories.

Zone E: This zone exhibits the deepest bedrock and deepest mud and the greatest potential settlement, in excess of six (6) inches over the next thirty years. Pile foundations will in all likelihood be required everywhere in Zone E, for buildings of any size.

3.0 BUILDING FOUNDATION TYPES

Basically there are two foundation types: shallow and pile. Shallow foundations may consist of conventional spread footings or stiffened slabs, depending on site specific soils conditions and structural needs. Piles may be either bearing or friction piles also depending on specific conditions. (See September 10, 1986 Memorandum #5, attached)

In Figure 6, the generalized foundation recommendations for this site are shown. Areas with less than two (2) inches expected settlement, areas with two-six (2-6) inches of expected settlement and areas with greater than six (6) inches expected settlement in the next thirty (30) years are shown. Existing or razed pile supported structure and existing dock weight fill, both of which affect differential settlement, are also shown. Implications for Mission Bay, based on the above figures are set forth in section 5.0 of this study.

4.0 COSTS

There is likely to be a cost premium, part of the construction cost, associated with building housing on the poorer soils in Mission Bay. However, the cost premium per dwelling unit of building housing on the poorer soils is expected to be more or less the same regardless of density. Nonetheless, higher density residential buildings should be located on the better soils to minimize the number of dwelling units paying the cost premium. Fewer units will pay the premium if the less dense housing is built on the poorest soils.

5.0 IMPLICATIONS FOR MISSION BAY

The generalized soils investigations to date permit some preliminary conclusions that should be used to prepare the Mission Bay Master Plan.

- In Zones A and B, pile foundations are probably necessary only for buildings six (6) stories or higher, although partial basements or depressed garages may be required for buildings over 2 stories.

- In Zones C and D, the greatest uncertainty about appropriate foundations exists. It is however likely that most buildings, certainly those six stories or higher will require pile foundations.

- In Zone E, pile foundations will in all likelihood be necessary for any building.

- Site preparation using wick drains and surcharging may not eliminate the need for other structural solutions such that it offers any clearly identifiable cost savings.

- There is a higher construction cost per square foot for housing built in poorer soils. This cost is higher in Zones D and E than in other zones because of expected areal settlement and the consequent need for pile foundations.

- Cost premiums in Zones D and E are not negligible. In Zones C, D and E, the costs per square foot of building increase at approximately the same rate regardless of density. For example, building four stories with concrete podium on piles is not significantly more economical per square foot than building eight stories with concrete podium on piles.

- Affordable housing should be located on better soils when possible. Locating housing on poor soils adversely affects afffordability.

- Recommendations that would be made for seismic safety on the site do not conflict with any of the above conclusions. (See Mission Bay Seismic Safety Study.)

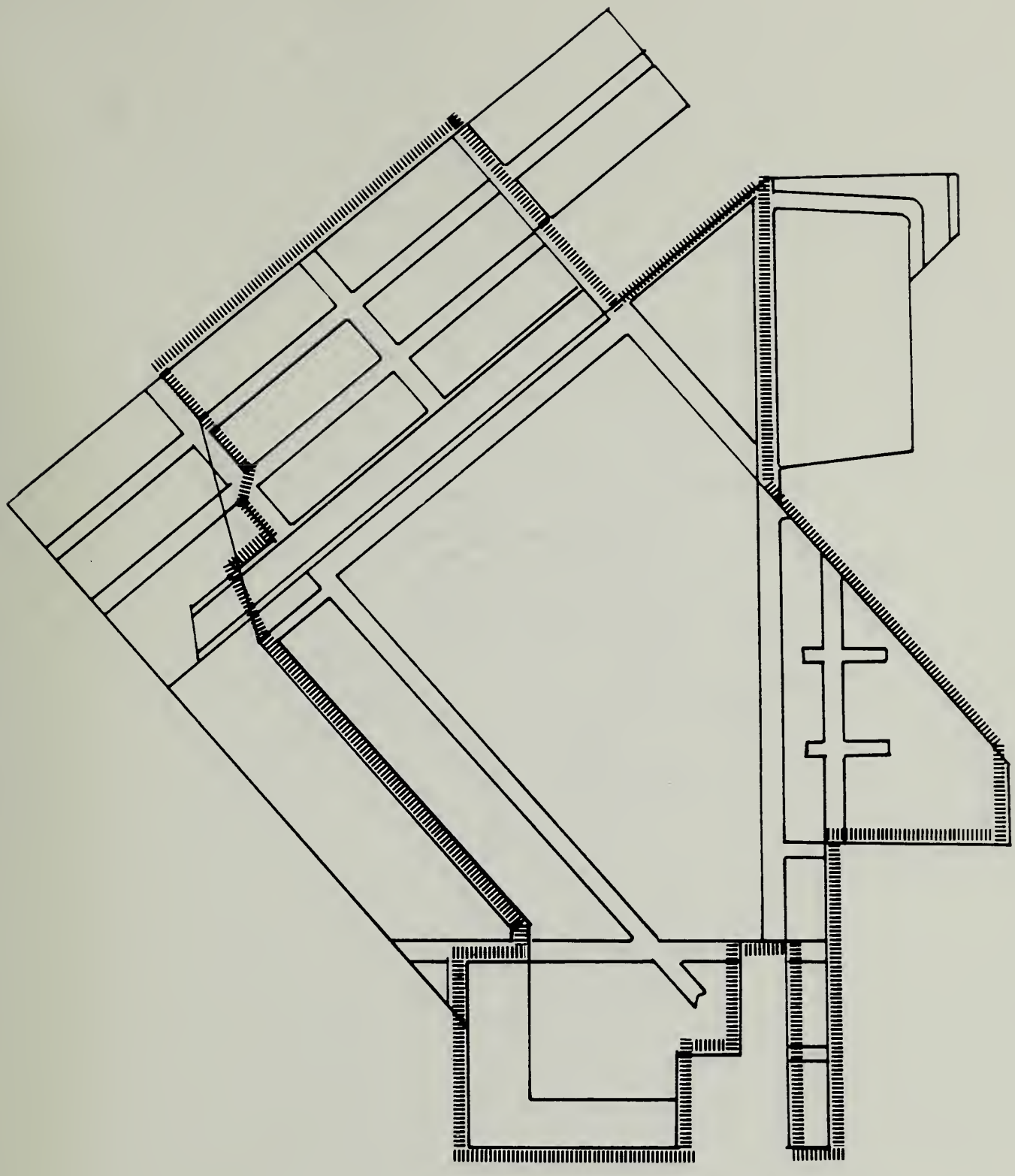


Figure 1

Potential Housing Areas

Source: Dames & Moore

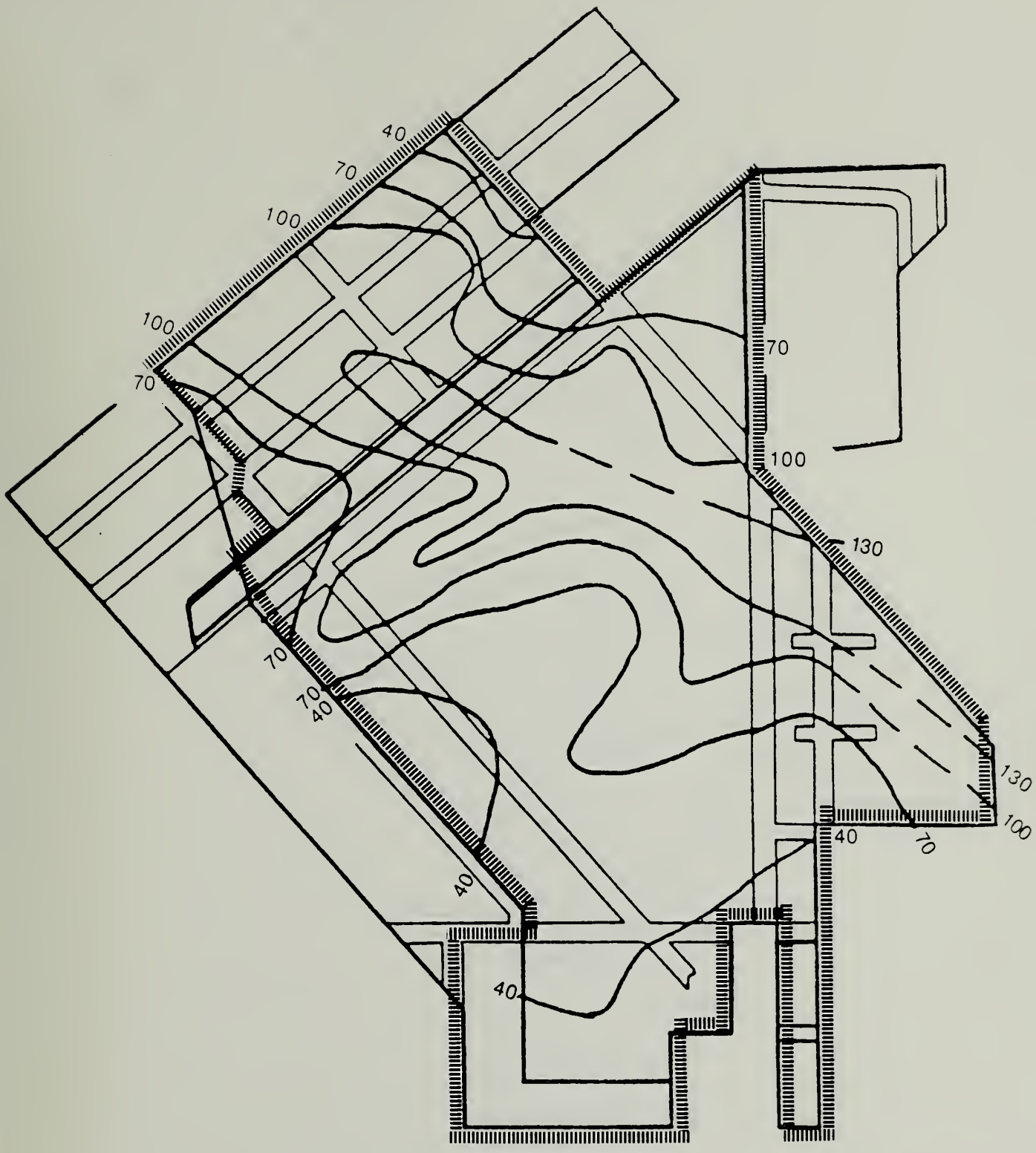


Figure 2

Bottom of Bay Mud

Source: Dames & Moore

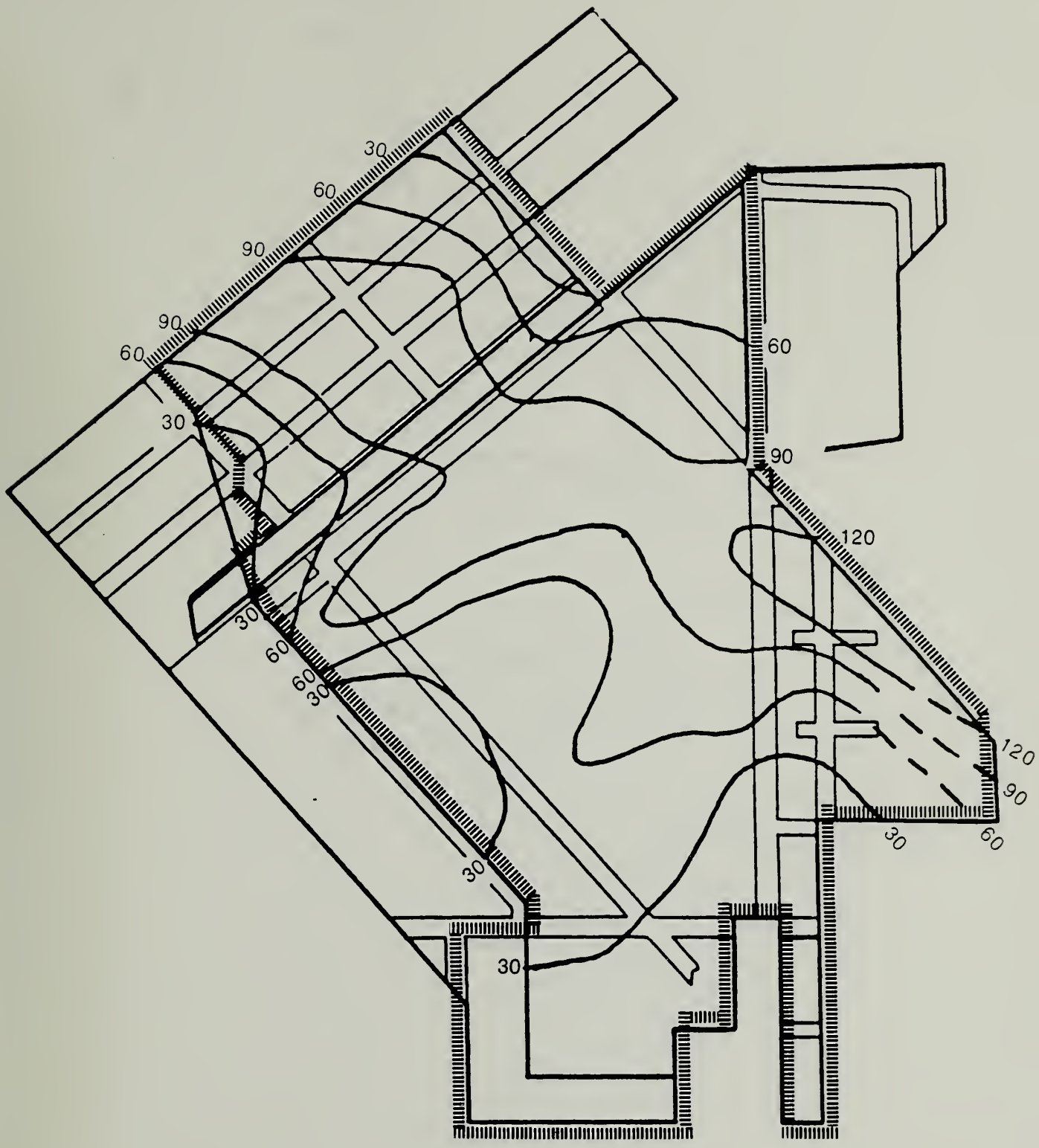


Figure 3

Thickness of Bay Mud

Source: Dames & Moore

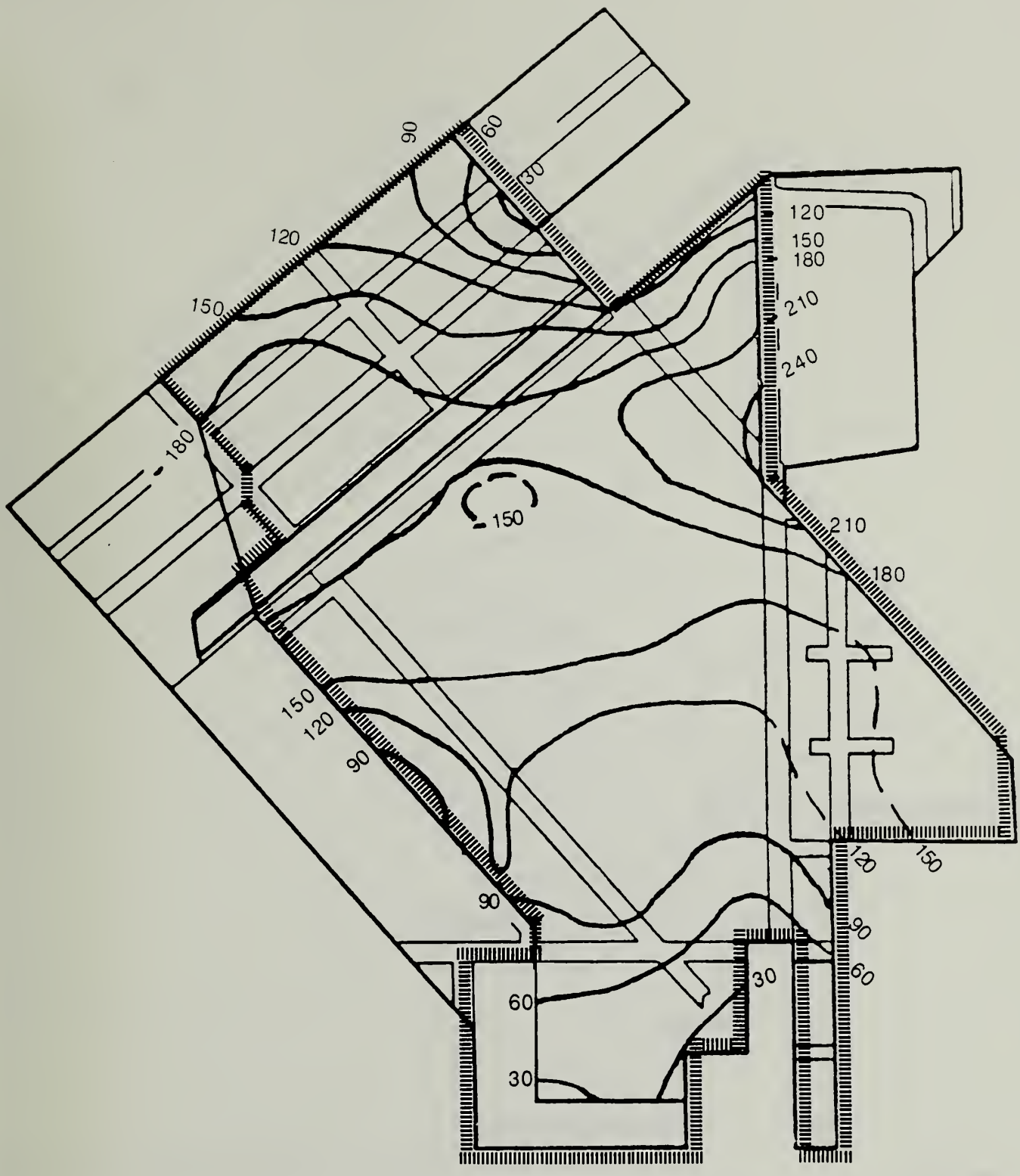
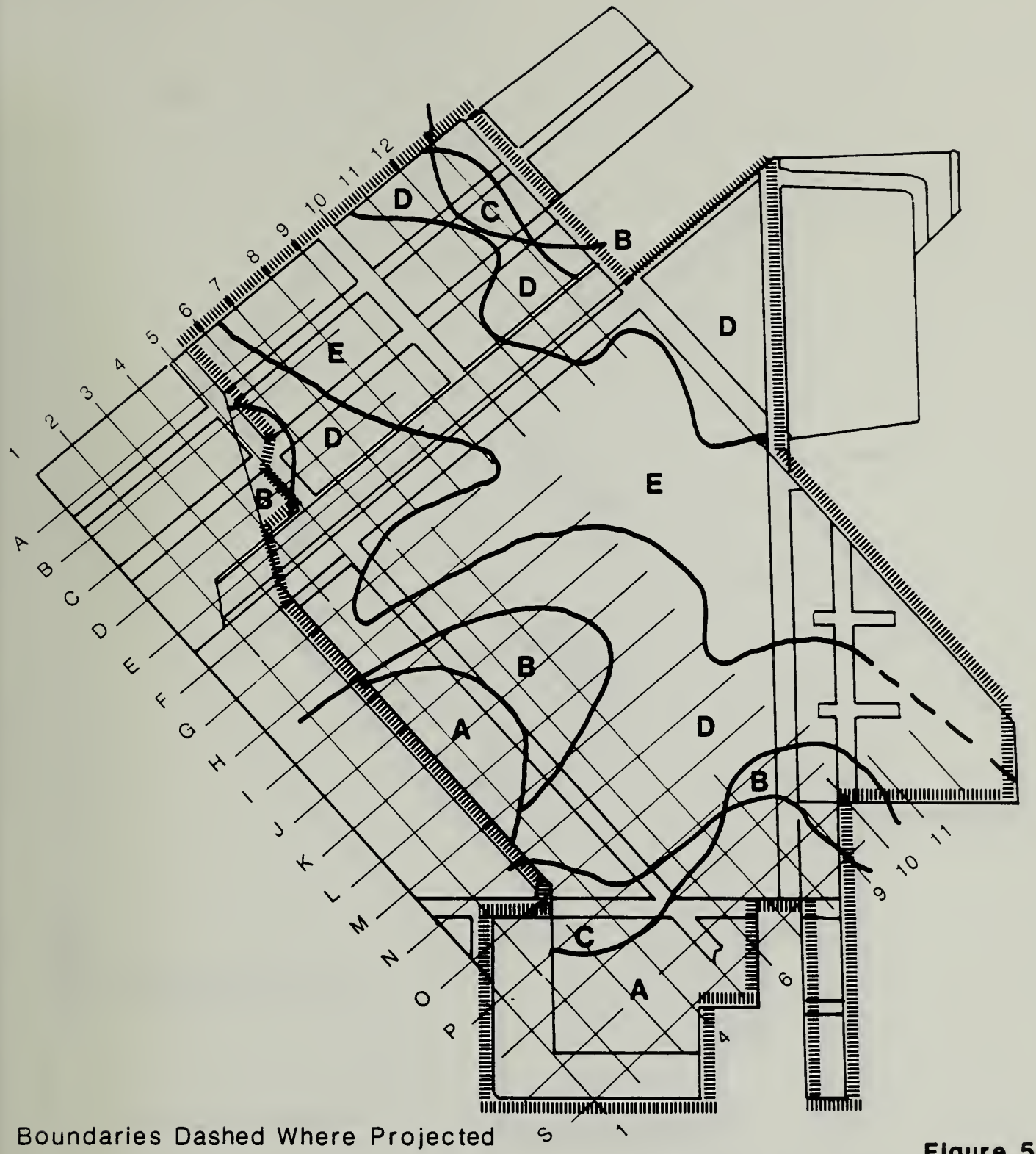


Figure 4

Top of Bedrock

Source: Dames & Moore



Boundaries Dashed Where Projected

Figure 5

Generalized Soils Zones

Zone	Anticipated Areal Settlement (inches)	Estimated Pile Lengths (feet)
A	< 2	< 90
B	< 2	90-150
C	2-6	< 90
D	2-6	90-150
E	> 6	> 100

Source: Dames & Moore

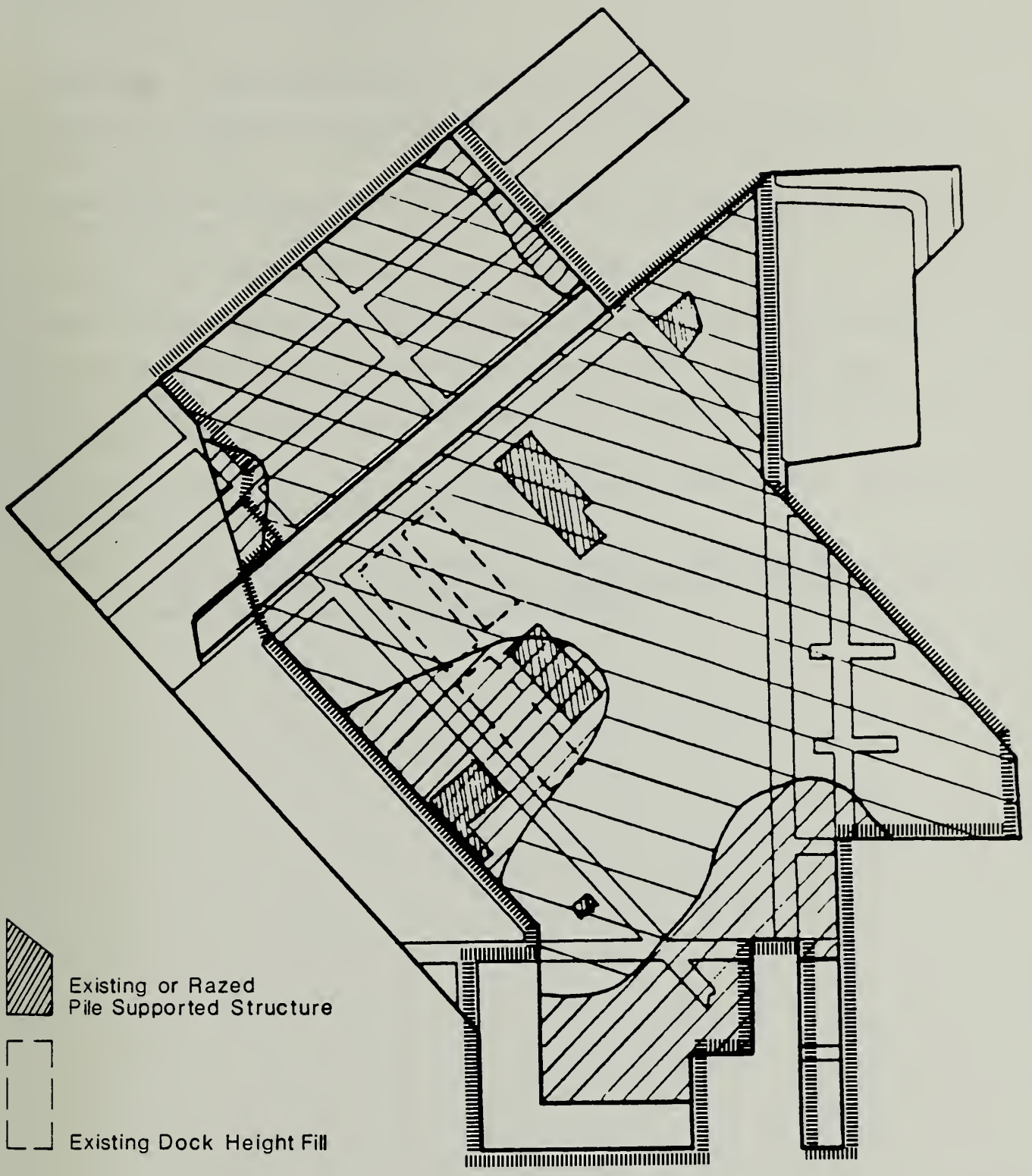


Figure 6

Generalized Foundation Recommendations

Housing
Study Area

Less Than 2 in. Expected Settlement
of Existing Fills in Next 30 Years

Greater Than 2 in. Expected Settlement
of Existing Fills in Next 30 Years

Source: Dames & Moore

Appendix A: Soils Investigations in Chronological Order

Geotechnical Consultation/Mission Bay Project, San Francisco, California. Dames & Moore. July 9, 1982.

Geotechnical Consultation/Mission Bay Project, San Francisco, California. Dames & Moore. December 1, 1982

Letter from EDAW to Santa Fe Pacific Realty Corporation. April 16, 1986.

Letter from Dames & Moore to Santa Fe Pacific Realty Corporation. April 29, 1986.

Letter from Daniel Solomon and Associates to Dames & Moore. August 19, 1986.

Letter from Shapiro, Okino, Hom & Associates to Daniel Solomon & Associates. August 29, 1986.

Memorandum No. 5 from Dames & Moore to Shapiro, Okino, Hom & Associates. September 10, 1986. (revised from 7/86 memo)

Notes: These documents are available for review in the Department of City Planning. Another Mission Bay Study, Seismic Safety, is related to this topic and is also available at the Department offices.

Appendix B: Recent Memos in Chronological Order

April 16, 1986

Mr. James Augustino
Santa Fe Pacific Realty Corporation
201 Mission Street, Suite 200
San Francisco, California 94105

Re: Site Suitability
Various Housing Types

Dear Jim:

Following is a description of several areas of inquiry which, if fully understood, will greatly enhance the Mission Bay planning process being undertaken by the San Francisco Department of City Planning. In general, a clear understanding is sought about the feasibility of developing various housing structures and types on the site. In particular, the constraints and costs that site soils place upon the construction of housing are of interest.

Planning for Mission Bay, to date, has indicated a need for substantial numbers of housing units, mostly in all-residential blocks. Those blocks should include a garage at the ground floor, covering most or all of the block and providing a podium level above it for some open space and several floors of housing units. A garage with its floor level below grade is desirable, but not essential. Internal to these blocks, narrow alleys and small public open spaces at grade are planned. Housing units in these blocks are planned at two to six floors, with party walls. Frequent entrances, including walkups, are planned along the perimeter of the block, as direct access to the housing. Thus, both the garages and housing entries are directly tied to the sidewalk. Mission bay housing is being planned to create fairly dense blocks and neighborhoods (40-80 DU/AC), similar to many of the neighborhoods within a couple of miles of the downtown area. Lastly, neighborhood quality or urban design character similar to nearby urban San Francisco neighborhoods is sought.

An evaluation of the technical feasibility of developing this type of housing is needed, as are general cost estimates that provide information about possible trade-offs in foundation, drainage and housing density for these units. The following questions are intended to guide this inquiry. A map of the site area where housing is planned is attached and illustrations of possible block and housing-types are attached.

EDAW inc.
Environmental Planning Urban Design Landscape Architecture
San Francisco Alexandria Irvine Fort Collins New Orleans Atlanta Seattle
1725 Montgomery Street, San Francisco, California 94111 Telephone (415) 433-1484 Telex 340604 License No. 1947

1. What types of foundations are appropriate for housing in this area?

   a. Are raft foundations feasible on the site. If so, where? If not, why not?

   b. Are raft foundations with wick drains feasible on the site. If so, where? If not, why not?

   c. If pile foundations are used where 2-inch to 6-inch differential settlement is likely to occur, what is the added cost for:

      (1) 2-story housing over wood-frame garage;

      (2) 3-story housing over wood-frame garage;

      (3) 4-story housing over concrete garage.

2. How can housing be directly tied to sidewalks in areas of significant differential settlement?

   a. What are associated costs?

   b. If a setback were required, what is the minimum feasible setback?

3. How can housing be directly tied to infrastructure in areas of significant differential settlement?

   a. What are associated costs?

4. To relieve surcharge, can garages be excavated to create garage floors 2 to 8 feet below grade?

   a. What are the cost trade-offs between at grade and below grade garages?

5. What are the comparative costs of woodframe buildings with wood garage and raft foundations versus woodframe buildings with wood garages and pile foundations.

6. Do wick drains make wood-frame buildings with wood garages and raft foundations feasible anywhere on the site? If not, why not?

   a. What is the appropriate size of a phase of development for wick foundations?

   b. What are tradeoffs in time versus money for wick foundations?

7. Are there any unique areas north of the China Basin Channel which result in in different answers to the above questions?

Please call me if you have questions.

Sincerely,

EDAW, Inc.

Teresa

N. Teresa Rea

B:86032412

MEMORANDUM #4

TO: Don Marini, Project Manager
Santa Fe Pacific Realty Corporation

DATE: April 29, 1986
JOB: 12756-004-03

CC: Daniel Shapiro
Shapiro Okino Hom and Associates

Bill Barton
KCA Engineers, Inc.

FROM: Bob Darragh and Mark Wahler
Dames & Moore

SUBJ: Preliminary Study of Drainage Wicks vs. Pile Foundations at Mission Bay

This memorandum discusses the pros and cons including approximate costs for drainage used wicks to pre-settle the Mission Bay site and eliminate or reduce the need for piles. The discussion herein is based on preliminary or estimated data. Further analyses would be required if drainage wicks are selected for use. This memo is laid out with a summary table of comparative costs for an example location (see Footnote) followed by a discussion of the assumptions made and the pros and cons of wicks vs. piles.

COMPARATIVE COSTS

Structure Case	$/ft*ft of Land	$/ft*ft of Superstructure
Low rise w/wicks	9.06	6.19
Low rise w/piles	9.15	6.25
Medium rise w/wick	9.06	3.87
Medium rise w/piles	10.30	4.40

Footnote:

- This comparison is made for a typical site near the channel and across from 5th street. 90 ft of Bay Mud were assumed to be overlain by 15 ft of fill.
- Costs for wicks includes wicks and surcharge fill. The surcharge was assumed to be in place for one year.
- Costs for piles and definitions for structures are taken from Spiegel and Zamecnik Inc.'s report of September 2, 1983. Costs include piles, pile caps, and tie beams.
- Low rise structure is three stories of dwelling over a garage. Medium rise is eight stories over a garage.
- In computing $/ft*ft of Land, the surrounding streets, alleys, and courtyards are included. However, the costs for the pile cases do not reflect the costs of protecting these areas from excessive settlements.
- For computing piles costs as a function of land, unit densities were inferred from the Proposed Land Use Program & Illustrative Plans - February 7, 1986. Low rise was assumed to be low-density at 75 DU/acre, 850 sq. ft. each, Medium rise was assumed to be higher density at 120 DU/acre, 850 sq. ft. each.

Example Calculations:

- Wick costs per square foot of land:

  The typical site was assumed to have 15 feet of old fill overlying 90 feet of Bay Mud. The current surface elevation was assumed to be the desired final elevation. Calculations based on estimated soil parameters for the example site and assuming that the surcharge was in place for one year indicated that wicks would be required to be in a triangular layout and separated 3.8 feet on center. The calculations assumed 2.5' of surcharge fill and indicate that 4 feet of settlement will have occurred at the end of one year, requiring 4 feet of permanent fill to maintain the current ground surface.

  Wicks were assumed to cost $0.80 per lineal foot installed (based on average costs of similar installations) plus a $5.00 cost per wick to cover the costs of any special set-up and predrilling if required. For the example site, 105 foot long wicks would be required to penetrate to the bottom of the Bay Mud, leading to a cost per wick of 105' x $.80 + $5.00 = $89.00. As each wick affects an area of 0.866 x D x D (where D is the wick separation of 3.8'), the cost per square foot of land for the wicks alone is $89.00 / (0.866 x 3.8 x 3.8) = $7.12. If the cost of permanent fill is $10.00 per cubic yard, and the cost of the removable (surcharge) fill is $5.00 (the lower cost reflects the reusability of the fill), then the total cost of the system is $7.12 + (4' x $10.00/cu yd + 2.5' x $5.00/cu yd) x 1/27 cu yd/cu ft = $9.06.

- Wick costs per square foot of low rise structure:

  As mentioned above, low rise structures were assumed to consist of 75 - 850 square foot units per acre. The "footprint" for each square foot of superstructure is 43560 square feet per acre / (75 units per acre x 850 square feet per unit) = 0.683 square feet of land per square foot of superstructure. The cost of wicks per square foot of structure are then 0.683 x $9.06 = $6.19.

- Wick costs per square foot of medium rise structure:

  As mentioned above, medium rise structures were assumed to consist of 120 - 850 square foot units per acre. The "footprint" for each square foot of superstructure is 43560 square feet per acre / (120 units per acre x 850 square feet per unit) = 0.427 square feet of land per square foot of superstructure. The cost of wicks per square foot of structure are then 0.427 x $9.06 = $3.87.

- Pile costs per square foot of structure:

  Costs for piles in terms of square feet of structure were taken from Spiegel and Zamecnik Inc.'s report, as mentioned above.

- Pile costs per square foot of land for low rise structure:

  Costs for piles in terms of square feet of land are computed in the reverse of the method used to convert wick costs to cost per square

foot of structure. Hence, $6.25 (from Spiegel, et. al.) / 0.683 = $9.15.

DISCUSSION OF WICKS

Wicks may be used in areas where unacceptable levels of anticipated settlements will occur. At the mission Bay site, this is currently assumed to be anywhere where the Bay Mud is in excess of 60 feet thick.

System Elements:

- Wicks. Wicks are prefabricated and generally made of man-made materials. The are pushed into the ground with a mandrel, generally on a triangular spacing. The wick spacing is a function of soil conditions, fill thickness, ground water level, and time available for consolidation.

- Surcharge fill. This is fill used to speed the consolidation time and to help reduce secondary consolidation. At the end of consolidation, it is removed and may be reused. The amount of fill required depends on the soil conditions and has an impact on the wick spacing. The optimum balance between wick spacing and fill thickness is partially a function of economics.

- Drainage blanket. Depending on the permeability of the fill (either old or new), a layer of free draining material may be required between the existing ground and the new fill.

Advantages:

The primary objective of a drainage wick program would be to reduce or eliminate post construction settlements, not only for the buildings, but for the adjacent areas including the streets. This can eliminate the need for deep piling in many cases, thereby simplifying the construction process. Additionally, as the entire site is treated, rather than just the structures, the costs incurred by settlements and settlement considerations for sewer-building connections, street maintenance costs, utility maintenance costs, and the impact of differential settlements on canals are reduced.

Disadvantages:

One major drawback of the drainage wick approach is the need to treat large areas in addition to the building footprint to be effective. The area treated would include all streets, alleys, and open areas adjacent to the structures. It must also extend a sufficient distance beyond the edge of the area to be pre-consolidated to eliminate edge effects, on the order of twice the depth to the bottom of the soft Bay Mud.

Another drawback is the need for the the wicks and surcharge fill to be in place for a minimum of six months, and generally longer, for the consolidation to take place. (Our cost estimate for the 90 foot mud thickness assumes one year and makes no allowance for the costs of delay). Further, a test fill should be made to determine the optimum wick spacing, which in turn could further delay the construction process. This is partially mitigated by being able to actually use the test area for construction without further consolidation.

Test Fill:

Prior to any major use of wicks, a test fill should be constructed to optimize the drain spacing. With a test fill, it would be desirable to evaluate at least two drain spacings, and maybe two brands of wicks. The minimum size for such a fill would be about one acre, with about four being preferable. It should be placed in an area with no existing structures or piles, and preferably where building will begin soon so that any induced benefits can be used. It may actually be desirable to place the fill over a larger area so that an entire building phase area can benefit. Such a location could be the area Southeast of the China Basin Channel and Southwest of Third Street. A high quality soils investigation and testing program would be required to select the best preliminary spacing estimates and to aid in extrapolating the results to other location. Additionally, a good estimate of the planned final grades, structure loads, and allowable time for the surcharge fill to remain in place would be required. During the test, a careful monitoring of actual settlements using well established settlement monuments would be performed to measure the effectiveness and settlement rates of the system. To obtain more than a ballpark estimate of the costs, a qualified contractor should be contacted to make the estimate.

AVAILABLE SETTLEMENT DATA

The City of San Francisco's Division of Surveys and Mapping has advised us that they have historic records of elevations taken at at least 30 of the street intersections in and adjacent to the project area, which we have obtained. These records will hopefully help us in evaluating the actual settlement history of the area, which in turn should permit better predictions of future settlements and the time rates of settlements.

Daniel Solomon, FAIA Architecture and Planning 84 Vandewater Street
San Francisco, California 94133
Telephone (415) 397-9190

August 14, 1986

Bob Darragh
Dames & Moore
500 Sansome St.
San Francisco, CA 94111

Dear Bob:

Enclosed you will find the list of housing prototypes we are developing in our "Special Studies" phase of work. We will need the range of substructure costs associated with each in each soil zone. Wherever it is possible to be specific with regards to the foundation type, i.e.: raft or piles, or the garage structure, i.e.: wood or conc., please indicate it. Please note that the average footprint relates to what we distinguish as a minimum developable parcel with a contiguous footprint without separation.

If you need additional information or clarification, please contact me.

Sincerely,

Kathryn Clarke

Kathryn Clarke

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AUG 14 1986
SHAPIRO · OKINO · HOM
& ASSOCIATES · ENGINEERS

KC/br

Enclosures

cc: Dan Shapiro

Mission Bay Special Studies
Housing Prototypes

I.	**High Density Townhouse**	2 levels No Garage
	. wood frame structure	30" X 17' footprint 59% lot coverage
	. tandem units with 3 level type	
clarify ?		
II A.	**High Density Townhouse**	2 levels & 1 level Garage
	. wood frame structure above garage	25' X 18' footprint 63% lot coverage
	. wood frame aggregate parking garage except where necessary concrete garage	
	. minimal developable parcel is eleven contiguous units of 2 and 3 level units (see attached)	U-shaped footprint 58% lot coverage
II B.	**Luxury Townhouse**	2 levels & 1 level Garage
	. wood frame structure above garage	40' X 25' footprint 73% lot coverage
	. wood frame individual parking garage except where necessary - concrete	
	. contiguous footprints range from 2 to 11 units	40' X 50' to 175' footprint 73% lot coverage
* II C.	**Stacked Flats Over Neighborhood Commercial**	2 levels & 1 level
	. wood frame structure above garage	% footprint lot coverage
	. wood frame aggregate parking garage with perimeter commercial except where necessary - concrete	
	. contiguous footprint at grade	% footprint lot coverage
III A.	**Stacked Flats**	3 levels & 1 level Garage
	. wood frame structure above garage	O-shaped footprint 64% lot coverage
	. wood frame aggregate parking garage except where necessary - concrete	
	. contiguous footprint at grade	285' X 150' footprint 100% lot coverage

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III B.	Stacked Flats Over Family Units	3 levels & 1 level Garage	
	. wood frame structure above garage	O-shaped 70%	footprint lot coverage
	. wood frame aggregate parking garage except where necessary - concrete		
	. contiguous footprint at grade	120' X 250' 100%	footprint lot coverage
* III C.	Owner Unit/Rental Unit	3 levels & 1 level Garage	
	. wood frame structure	50' X 50' 70%	footprint lot coverage
	. wood frame aggregate parking garage except where necessary - concrete		
	. contiguous footprint	% 	footprint lot coverage
IV A.	Stacked Flats Over Duplex Units	4 levels & 1 level Garage	
	. wood frame structure above garage	140' X 50' 75%	footprint lot coverage
	. concrete aggregate parking garage		
	. contiguous footprint at grade	140' X 120' 100%	footprint lot coverage
* IV B.	Stacked Flats Over Retail - Office Podium	3 levels & 2 levels Podium	
	. wood frame structure above podium	% 	footprint lot coverage
	. concrete podium - at grade, perimeter retail with aggregate parking interior - at second level, perimeter office with aggregate parking interior		
	. contiguous footprint at grade	100%	footprint lot coverage

V	Maximum Density Mid Rise Over Retail - Lobby Podium	6 levels & 2 levels Podium	
	. concrete structure - type 1 above podium	100' X 80'	footprint
		74%	lot coverage
	. concrete podium - at grade, perimeter retail and lobby with aggregate parking interior - at second level, aggregate parking		
	. contiguous footprint at grade	240' X 385'	footprint
		100%	lot coverage

General Comments

. A compensating basement 3'-0" to 4'-0" below grade is feasible and preferable in prototypes III A,B - IV A,B - and V.

. Building separations may be required where disparate foundations are adjacent or contiguous footprint is at the maximum within given parameters.

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August 29, 1986

Daniel Soloman & Associates, Architects
84 Vandewater Street
San Francisco, CA 94133

Attn: Daniel Soloman

Subject: Response to Letter of April 16, 1986
from EDAW to Santa Fe Realty Corp.
Site Suitability
Various House Types

Dear Dan,

This letter provides a response to the questions posed in the subject letter for which Shapiro, Okino, Hom and Associates was responsible.

Question 1:

What types of foundations are appropriate for housing in this area?

a. Are raft foundations feasible on the site? If so, where? If not, why not?

Raft foundations are feasible for this site in certain locations and certain housing types. The location is determined by the "amount of anticipated areal settlement" while the housing type is determined by the number of stories. The Dames and Moore letter gives the relation of settlement and number of stories to allow raft foundations.

b. Are raft foundations with wick drains feasible on the site? If so, where? If not, why not?

See Dames and Moore letter.

c. If pile foundations are used where 2-inch to 6-inch differential settlement is likely to occur, what is the added cost for:

1) 2-story housing over wood-frame garage;
2) 3-story housing over wood-frame garage;
3) 4-story housing over concrete garage.

Before these questions can be answered in a qualitative manner, a number of assumptions need to be made:

1) Additional cost refers to cost difference between raft supported housing versus pile supported housing.

2) Zones C and D have 2" to 6" of settlement. Locations of differential settlement have not been determined by soils engineer and it may not be appropriate at this time to the cost.

3) Costs are given as dollars per square foot of foundation footprint.

#	Housing Type	Zone 'C'	Zone 'D'
1	2-story housing over wood-frame garage	18.00	27.00
2	3-story housing over wood-frame garage	18.00	27.00
3	4-story housing over concrete garage	19.00	30.00

Question 2:

How can housing be directly tied to sidewalks in areas of significant differential settlement?

a. What are associated costs?

b. If a setback were required, what is the minimum feasible setback?

Yes, sidewalks can be tied to housing in areas of significant settlement. This can be accomplished by hinging the sidewalk off of the building. The associated costs during construction are nominal. Additional costs will occur in the future due to maintenance. The width of the sidewalk should not exceed 15' so this gives the maximum setback from the street.

Question 3:

How can housing be directly tied to infrastructure in areas of significant differential settlement?

a. What are associated costs?

See report by KCA.

Question 4:

To relieve surcharge, can garages be excavated to create garage floors 2 to 8 feet below grade?

a. What are the cost trade-offs between at grade and below grade garages?

Yes, to relieve surcharge due to building loads, garages can be excavated 1 foot for every story in certain locations. This recommendation by the soils engineer has a limit of 5 feet excavation for a 5-story building. This will allow non-pile supported buildings in certain zones of the site. The cost trade-off between at grade and below grade are:

Cost	At Grade Garage	Below Grade Garage
Saving	1) Excavation 2) Waterproofing 3) Basement Walls 4) Stiffened Slab-on-Grade	1) No piles for certain bldgs. in certain locations 2) Structural Slab
Addition	1) Piles for certain bldgs. in certain locations 2) Structural Slab	1) Excavation 2) Waterproofing 3) Basement Wall 4) Stiffened Slab-on-Grade

Question 5:

What are the comparative costs of woodframe buildings with wood garage and raft foundations versus woodframe buildings with wood garages and pile foundations?

The comparative cost between raft foundations and pile foundations are shown in Table 1.

Question 6:

Do wick drains make wood-frame buildings with wood garages and raft foundations feasible anywhere on the site? If not,

why not?

a. What is the appropriate size of a phase of development for wick foundations?

b. What are tradeoffs in time versus money for wick foundations?

See report by Dames and Moore.

Question 7:

Are there any unique areas north of the China Basin Channel which result in different answers to the above questions?

See report by Dames and Moore.

If you have any questions, please feel free to call.

Sincerely,

Patrick Buscovich

PB/cs

cc: Alec Bash/Dept. of City Planning

TABLE 1 TOTAL COST $/ϕ (FOUNDATION FOOTPRINT)

TYPE	CONST.	A S	A P	B S	B P	C S	C P	D S	D P	E S	E P
I	2W	6.00		6.00		6.00	26.00	6.00	35.00		61.00
IIA	3W	9.00		9.00		9.00	27.00	9.00	36.00		66.00
B	3W	9.00		9.00		9.00	27.00	9.00	36.00		66.00
C	3W	9.00		9.00		9.00	27.00	9.00	36.00		66.00
	2W/1C	9.00		9.00		9.00	28.00	9.00	39.00		71.00
IIIA	4W	9.00		9.00		9.00	27.00	9.00	37.00		67.00
	3W/1C	9.00		9.00		9.00	28.00	9.00	39.00		71.00
B	4W	9.00		9.00		9.00	27.00	9.00	37.00		67.00
	3W/1C	9.00		9.00		9.00	28.00	9.00	39.00		71.00
C	4W	9.00		9.00		9.00	27.00	9.00	37.00		67.00
IVA	5W	9.00		9.00		9.00	27.00	9.00	37.00		68.00
	4W/1C	9.00		9.00		9.00	28.00	9.00	39.00		74.00
B	3W/2C	9.00		9.00		9.00	30.00	9.00	42.00		80.00
V	8C		27.00		36.00		38.00		69.00		125.00

NOTES:

1) SEE ATTACHED LETTER BY DAN SOLOMON FOR DESCRIPTION OF HOUSING TYPES.
2) DELETED BOXES ARE AREAS THAT SOILS ENGINEER DOES NOT RECOMMEND FOR THIS FOUNDATION TYP A, B, C, D, E, SOIL
3) W - WOOD FRAMING
C - CONCRETE FRAMING
S/P SHALLOW FOUNDATION/PILE
4) TABLE 1 IS COST OF FOUNDATION ONLY.

TABLE 2 TOTAL COST / TOTAL SQUARE FOOTAGE $/ϕ

TYPE	STORIES	CONST.	A S	A P	B S	B P	C S	C P	D S	D P	E S	E P
I	2	2W	3.00		3.00		3.00	13.00	3.00	17.50		32.00
IIA	3	3W	3.00		3.00		3.00	9.00	3.00	12.00		22.00
B	3	3W	3.00		3.00		3.00	9.00	3.00	12.00		22.00
C	3	3W	3.00		3.00		3.00	9.00	3.00	12.00		22.00
		2W/1C	3.00		3.00		3.00	9.33	3.00	12.33		21.67
IIIA	4	4W	2.25		2.25		2.25	6.75	2.25	9.25		16.75
		3W/1C	2.25		2.25		2.25	7.00	2.25	9.75		18.50
B	4	4W	2.25		2.25		2.25	6.75	2.25	9.25		16.75
		3W/1C	2.25		2.25		2.25	7.00	2.25	9.75		18.50
C	4	4W	2.25		2.25		2.25	6.75	2.25	9.25		16.75
IVA	5	5W	1.40		1.40		1.40	5.40	1.40	7.40		13.60
		4W/1C	1.40		1.40		1.40	5.60	1.40	7.80		14.80
B	5	3W/2C	1.40		1.40		1.40	6.00	1.40	8.40		16.00
V	8	8C		3.38		4.50		4.75		8.63		15.63

NOTES:

1) SAME AS ABOVE
2) SAME AS ABOVE
3) SAME AS ABOVE
4) TABLE 2 IS TABLE 1 DIVIDED BY NUMBER OF STORIES.

TABLE 3 PREMIUM COST OF FOUNDATION $/ϕ

TYPE	CONST.	A S	A P	B S	B P	C S	C P	D S	D P	E S	E P
I	2W	ϕ		ϕ		ϕ	20.00	ϕ	29.00		58.00
IIA	3W	3.00		3.00		3.00	21.00	3.00	30.00		60.00
B	3W	3.00		3.00		3.00	21.00	3.00	30.00		60.00
C	3W	3.00		3.00		3.00	21.00	3.00	30.00		60.00
	2W/1C	3.00		3.00		3.00	22.00	3.00	33.00		68.00
IIIA	4W	3.00		3.00		3.00	21.00	3.00	31.00		61.00
	3W/1C	3.00		3.00		3.00	22.00	3.00	33.00		68.00
B	4W	3.00		3.00		3.00	21.00	3.00	31.00		61.00
	3W/1C	3.00		3.00		3.00	22.00	3.00	33.00		68.00
C	4W	3.00		3.00		3.00	21.00	3.00	31.00		61.00
IVA	5W	3.00		3.00		3.00	21.00	3.00	31.00		62.00
	4W/1C	3.00		3.00		3.00	22.00	3.00	33.00		68.00
B	3W/2C	3.00		3.00		3.00	24.00	3.00	36.00		74.00
V	8C		ϕ		9.00		11.00		42.00		98.00

NOTES:

1) SAME AS ABOVE
2) SAME AS ABOVE
3) SAME AS ABOVE
4) PREMIUM COST IS ADDITIONAL COST OF FOUNDATION ON THIS SITE VERSUS A TYPICAL FOUNDATION.

TYPICAL:
I-II 6.00 V 27.00
III-IV 9.00 PILE

MEMORANDUM #5

TO: Daniel Shapiro
Shapiro, Okino, Hom and Associates

CC: Don Marini, Project Manager
Sante Fe Pacific Realty Corporation

Alec Bash
Department of City Planning

N. Teresa Rea
EDAW

Bill Barton
KCA Engineers, Inc.

FROM: Bob Darragh and Mark Wahler
Dames & Moore

SUBJ: Site Suitability for Various Housing Types

This memorandum provides answers to the questions posed in the April 16, 1986 letter from EDAW (N. Teresa Rea) to Santa Fe Realty Corporation (James Augustino) for which Dames & Moore was responsible; the balance of the answers will be provided by others. The scope of this memo is as outlined in the June 2, 1986 letter from Shapiro, Okino, Hom & Associates (Daniel Shapiro) to the Department of City Planning (Alec Bash).

This memorandum consists of the following five sections:

- RESPONSE TO EDAW'S QUESTIONS
- SOIL ZONES FOR FOUNDATION COSTS
- DISCUSSION
- BACKGROUND STUDIES
- REFERENCES

RESPONSE TO EDAW'S QUESTIONS

The responsibility for responding to EDAW's questions was divided between Dames & Moore and Shapiro, Okino, Hom and Associates. Following are Dames & Moore's responses. Those questions followed by "(SOH)" will be addressed by Shapiro, Okino, Hom and Associates, with consultation from KCA and Williams & Burrows as needed. Many of the recommendations presented in this section were taken from earlier Dames & Moore reports and memorandums.

Question 1: What types of foundations are appropriate for housing in this area?

For the purpose of this discussion, the housing study area is divided into three general categories, the first being those areas where less than 2 inches of areal settlement is expected during the next 30 years, the second being where 2 to 6 inches of areal settlements are expected, and the third being where more than 6 inches of areal settlements are expected (see Plate 1). These projected settlements are due to the existing areal fills on the site and assume that no new areal fills are placed.

Due to the limited extent of our subsurface information, the location shown on Plate 1 for the dividing lines between the three zones is only approximate. We feel, however, that the relative proportion of the three areas and their general locations are reasonably accurate.

The following table presents our general foundation recommendations and is followed by a discussion for each housing height group. Further discussion of each of the foundation types mentioned may be found in the section titled "DISCUSSION", below.

RECOMMENDED HOUSING FOUNDATION TYPES

Building Height (stories)	Basements?	Maximum Amount of Anticipated Areal Settlement	
		Less than 2 inches	Greater than 2 inches
1-2	Yes or No	Shallow Foundations	Piles/Shallow Foundations*
2-5	No	Piles	Piles
2-5	Yes	Shallow Foundations	Piles/Shallow Foundations*
6-8	Yes or No	Piles	Piles

*Under certain circumstances, shallow foundations may be satisfactory where relatively uniform settlements are expected within the building footprint (see "DISCUSSION", below). For planning purposes, only piles should be considered where more than 6" of areal settlement are anticipated.

Shallow foundations may consist of conventional spread footings or stiffened slabs, depending on actual soil conditions and structural needs. Pile foundations may be of either bearing or friction type, also depending on actual conditions.

For the purposes of this memo, the term "basement" is used interchangeably with compensating foundations (see "DISCUSSION", below). Adequately depressed garages under the structures would meet this definition.

Low-Rise Housing Structures (1-5 stories). There are five general foundation solutions for low rise structures within the housing study area.

1. Conventional spread footings for one to two story structures without basements in areas where areal settlements of less than two inches and acceptable differential settlements are anticipated. Based on the limited available geotechnical information, such conditions are anticipated in roughly half of the housing study designated as settling less than 2" over 30 years. The actual locations where such foundations may perform adequately is dependent on a highly complex set of conditions and cannot be accurately determined without detailed site investigations.

2. Stiffened slabs for one to two story structures without basements in areas where acceptable differential settlements are anticipated. We anticipate that such foundations may be used in all areas where less than 2" of areal settlements are anticipated and, in certain circumstances, in areas where less than 6" of areal settlements are anticipated.

3. Compensating (or floating) foundations for buildings with basements up to 5 stories in areas where less than 2" of areal settlement are anticipated and in certain circumstances where less than 6" of areal settlements are anticipated (see Plate 1).

In considering shallow foundations special attention must be paid to areas presently or previously occupied by buildings with dock height fills or pile foundations. These building areas are shown dashed or cross hatched on Plate 1. Unless the footprint of the new buildings is within the former building area, shallow footings are probably not feasible. The differential settlement problem is more severe in the area where greater than 6 in. of areal fill settlements is expected; for the purposes of this study shallow footings should not be considered feasible in the building areas shown on Plate 1.

4. Deep piles in areas where anticipated areal settlements exceed 2" over the next 30 years (see Plate 1). These areas are estimated to make up 78% of the housing study area. Specific length recommendations have been updated from those presented in our December 1982 report and are presented on Plate 2.

   Within the housing study area there are a few existing or demolished pile supported structures. It may be possible to use these existing piles to support new structures. A number of these structures are shown on Plate 1. Additionally, the Interstate 280 decks and ramps are pile supported, but it is unlikely that those piles can be utilized effectively for housing structures.

5. Conventional spread foundations in areas that have been preconsolidated through the use of drainage wicks as discussed in our memorandum of April 29, 1986, entitled "Preliminary Study of Drainage Wicks vs. Pile Foundations at Mission Bay" (copy attached) or other similar means. Compensating or partially compensating foundations may also be used in these areas to reduce the amounts of surcharge fills required to balance the structural loads (see discussion on wicks below in the "DISCUSSION" section).

Medium-Rise Housing Structures (6 to 8 stories). As currently envisioned, all structures of this type will be located north of the channel between 4th Street and the I-280 Freeway. We believe that most medium rise structures in this area will require pile support. Specific length recommendations have been updated from those presented in our December 1982 report and are presented on Plate 2.

While in theory medium rise structures could be supported on compensating foundations, such floating foundations for residential structures have not been used to our knowledge for any housing units in areas of significant settlements. For conceptual planning, we recommend that compensating foundations be considered only for the low rise structures. Further, without the use of drainage wicks, there are only a few small areas in the housing study area north of the channel where settlements of less than 2 inches are predicted. If drainage wicks are selected for further consideration, a case by case assesment should be made when the actual soil conditions are better known as to the practicality of using compensating foundations for medium-rise structures.

Question 1a: Are raft foundations feasible on the site. If so, where? If not, why not?

For the purpose of this report "raft foundation" is used to mean compensating (or floating) foundations. Such foundations are considered feasible for building up to 5 stories in areas as shown on Plate 1 where future areal fills are less than 2 inches and in certain circumstances for areas of greater than 2 inches of future fill settlements, assuming that no new areal fills are placed, or other adverse local soil conditions exist.

Question 1b: Are raft foundations with wick drains feasible on the site. If so, where? If not, why not?

Raft foundations may be used in any area on the site where future potential settlements have been reduced to less than 2 inches through the proper use of wick drains and surcharge fills (see attached memo on wicks). While we anticipate that this would be the case everywhere on the site, there may be a few areas where a combination of unfavorable soil conditions may make this approach impractical. This can be accertained only by a thorough, site specific geotechnical investigation.

Question 1c: (SOH)

Question 2: (SOH)

Question 3: How can housing be directly tied to infrastructure in areas of significant differential settlement?

The housing structures should be connected to the infrastructure with flexible connections. These connections should be designed to accommodate the expected differential settlements. Particular care will be required with gravity flow sewers as they will be connecting to the city's existing pile supported sewer system.

Similar flexible connections will be required between the structurally independent sub-units of a housing block.

Information on details of actual methods and procedures should be obtained from KCA.

Question 3a: What are the associated costs? (KCA or W&B)

Question 4: To relieve surcharge, can garages be excavated to create garage floors 2 to 8 feet below grade?

Yes, this is, in essence, what we describe as a compensating foundation in our response to question 1. It should be noted that this method will only compensate for the surcharge created by the building itself, and can not be used to compensate for the effects of new or old areal fills. We do not recommend this approach for structures of more than five stories (including garage) or in areas where more than 6" of areal settlements are anticipated (see Plate 1 for appropriate areas). In areas where 2" to 6" of areal settlements are anticipated, this approach may be used under certain circumstances.

If garages are placed below grade, careful attention will have to be paid to the location of the ground water table.

Question 4a: What are the cost trade-offs between at grade and below grade garages? (SOH)

Elements to consider for at grade garages:

- Impact of differential settlements within the structure or costs of providing a rigid foundation to resist the differential settlements. Alternatively, pile supporting.

- Impact of differential settlements between the structure and the adjacent infrastructure and sidewalks

Elements to consider for below grade garages

- Costs of excavating
- Possible costs of water-proofing

Question 5: What are the comparative costs of woodframe buildings with wood garages and raft foundations versus woodframe buildings with wood garages and pile foundations. (Question amended by Alec Bash to include wood frames with concrete garages on raft or pile foundations)? (SOH)

From a geotechnical point of view, the slight weight benefit gained by using wood framing instead of concrete for garage construction is inconsequential when compared to the weight of the existing fills and any new fills placed for grading purposes. If raft foundations are employed, the loss of rigidity due to the use of wood garages may have to be made up for by using a stiffer foundation mat.

Question 6: Do wick drains make wood-frame buildings with wood garages and raft foundations feasible anywhere on the site?

Properly done drainage wicks with preloads would make wood-frame buildings with wood garages and raft foundations feasible in the majority of the site, although careful attention will have to be payed to the potential effects of soil recompression and secondary consolidation in areas of thicker bay mud deposits.

Question 6a: What is the appropriate size of a phase of development for wick foundations?

From a geotechnical standpoint, the minimum size for a phase should be one block. While the optimum size of a phase of development for wick drains is primarily based on economics, use of the wick system approach creates certain constraints which make it desirable to maximize the size of each construction phase. Since specialized construction equipment is required to install the drainage wicks, mobilization costs are relatively high.

Question 6b: What are trade-offs in time versus money for wick foundations?

A proper economic analysis of the costs and savings for the drainage wick approach as compared to piles must take into account the adverse impact of the loss of usage of the land during the wick construction and settlement phases as well as long term benefits, both in terms of maintenance costs and aesthetics, of reduced differential settlements on streets, utilities, and canals within the site. A discussion of the costs and benefits of a drainage wick system was discussed in our memo "Preliminary Study of Drainage Wicks vs. Pile Foundations at Mission Bay", dated April 29, 1986, which is attached to this memo.

In comparing different drainage wick and surcharge fill plans, the following rough guidelines may be used:

- The number of drainage wicks required per acre is roughly inversely proportional to the time required for the desired degree of settlement to occur. In the example we presented in our April 29 memo, where the wicks were assumed to

be in place for one year, the costs of the drainage wicks themselves represented about 75% of the total system costs.

- The thickness of surcharge fill used (in addition to the amount required to account for the induced settlement) also has an impact, with the more fill used, the shorter the amount of time required to reach the desired degree of consolidation (or, the greater the wick separation may be). The relationship between the two is, however, complex and is highly dependent on a number of other factors, including the amount of old fill, the degree of consolidation of the fill under the old fill, and the amount of fill required to account for the induced settlement. For the example cited above, a doubling of the amount of surcharge fill may allow a 5% to 10% reduction in the number of drainage wicks required, or a similar reduction in the time required to reach the desired degree of consolidation.

Question 7: Are there any unique areas north of the China Basin Channel which result in different answers to the above questions?

Not in light of the available limited geotechnical information. As with the entire site, detailed geotechnical investigations may detect local subsurface conditions that are either better or worse than than the soil conditions used in the current analyses.

While site specific geotechnical evaluations will be required for each structure, the preceding foundation recommendations should be satisfactory for conceptual planning and preliminary cost analyses of foundation alternatives. Background for these recommendations can be found in Dames & Moore's earlier reports and memos (see list of references at the end of this memo).

SOIL ZONES FOR FOUNDATION COSTS

As an aid in preparing cost estimates for various housing alternatives during the planning process, the housing study area can be broken into a number of generalized zones based on existing soil conditions. Two soils parameters can be assumed to control the foundation selection and costs for the housing types to be considered. They are the amount of anticipated settlements due to existing areal fills and the estimated lengths of piles for pile foundations.

On page two we presented a table which shows the relationship between anticipated areal settlement and foundation type. If this table is used with Plate 1 from the same memo, the site can be readily divided into three zones of recommended foundation types for a given structure type.

For pile supported structures, the lengths of the piles becomes a factor in the construction costs. Plate 2 shows estimated contours at 30 foot intervals for the housing study area. These contours can be used to define 3 zones based on pile length (<90', 90'-150', >150'). If pile costs are extracted from sheet S11 of Spiegel and Zamecnik Inc.'s "Report on Structural Systems for Buildings of Varying Heights and Foundation Conditions - With Costs" for Mission Bay, dated September 2, 1983, these zones then represent increments of about $2 per square foot of superstructure floor area.

Combining these two patterns results in the system of 5 zones for the housing study area shown on Plate 7 and described in the following table:

SOIL ZONES

Zone	Anticipated Areal Settlement (inches)	Estimated Pile Lengths Range (feet)	Estimated Pile Lengths Typical (feet)	Percent of Housing Study Area
A	< 2	< 90	50	13
B	< 2	90 - 150	100	9
C	2-6	< 90	75	4
D	2-6	90 - 150	110	40
E	> 6	> 100	175	34

Zone E contains all areas where the estimated pile lengths are greater than 150 feet plus a few small areas where the estimated pile lengths are between 100 feet and 150 feet where the anticipated areal settlement exceeds six inches.

The following table summarizes our general foundation recommendations for each of these zones.

RECOMMENDED HOUSING FOUNDATION TYPE BY ZONE

Building Height (stories)	Basements?	Soil Zone From Plate 7 A	B	C	D	E
1-2	Yes or No	S	S	P/S	P/S	P
2-5	No	P	P	P	P	P
2-5	Yes	S	S	P/S	P/S	P
6-8	Yes or No	P	P	P	P	P

where S = Shallow Foundations,
P = Piles, and
P/S = Piles or shallow foundations, depending on actual conditions.

DISCUSSION

The following section contains brief discussions of some of the various foundation elements discussed above.

Stiffened Slabs

These are floor slabs that have been stiffened with either structural elements underneath (such as waffle-slabs) or with post tensioning tendons. This stiffening may be used to resist the effects of differential settlements over short distances. The optimum dimensions of such slabs is dependent on the actual layout of residential units within a building. Individual slabs and their overlying subsections of buildings shall be separated with construction joints.

Compensating Foundations

Buildings constructed on floating foundations, with basement excavations which remove existing fills of equal or greater weight than the building, will settle about the same as the adjacent areal fills. For conceptual planning purposes, we recommend that floating foundation schemes be based on the assumption

that one foot of excavation is required for each story of building (including basement). This method requires a fairly stiff foundation to resist differential settlements due to uneven areal settlements and uneven load distributions under the foundations.

At this time, it is not possible to determine whether spread footings or stiffened slabs will be required for structures with compensating foundations. Individual spread footings may be adequate in some cases for low-rise buildings with the most favorable soil conditions. However, for initial cost estimates, it is recommended that stiffened slab foundations be assumed and that a premium of 50 percent be added to the normal cost of the basement and slab foundation systems to allow for additional structural elements to minimize differential settlement effects.

Piles

Deep piles may be of either friction or bearing type, depending on the actual site soil conditions and structural needs. Specific length recommendations appear on Plate 2, Pile Lengths, which is an updated version of the plate presented in our December 1982 report. For structures located in areas of significant anticipated settlements, pile design will need to include possible downdrag effects. Additionally, in such areas, allowance will have to be made for the effects of the differential settlements between the structures and connecting utilities, sidewalks and streets.

A further discussion of piles may be found in Dames & Moore's report "Geotechnical Consultation, Mission Bay Project, San Francisco, California", dated December 1, 1982.

Drainage Wicks

For maximum effect, wicks and there associated fills will have to be placed within the entire footprint of the buildings and streets within a phase (although large open spaces where long term settlements are not a concern may be left untreated). Along phase boundaries adjacent to future phases, the wicks will need to extend across the intervening streets. This will allow the streets to act as a buffer between adjacent phases. It may also be desirable to extend the wicks slightly into the next phase area to allow for the placement of surcharge fills for the next phase without blocking the streets. Along phase boundaries adjacent to future phases, the surcharge fills for the current phase must extend a distance estimated to be equal to 1.5 times the depth to the bottom of the bay mud beyond the edge of the drainage wicks. This margin is required to reduce settlements induced by the future placement of fills and strucrures in adjacent phases.

More rigid foundations may be required in areas where significant recompression and secondary compression may might occur. While we can not accurately predict if and where such conditions may exist, they would likely occur in those areas where the bay muds and fills are thickest (perhaps where the depth to the bottom of the bay mud is greater than 100 feet below current grade - see Plate 4A).

As an alternative, it may be possible to place the drainage wicks solely within the footprints of the structures, leaving the streets to settle normally. While the surcharge fills would need to extend beyond the wick area as before, this approach would result in the use of substantially fewer wicks than would be

needed if the streets and sidewalks were also treated. However, the same problems with differential settlements between the streets and structures will be encountered as would be for pile supported structures.

"Certain Circumstances"

There are two general categories of "certain circumstances" where shallow foundations may be used in areas where greater than 2 inches of areal settlements are anticipated:

1) Structures of sufficiently small footprint such that the structure or foundation could be reasonably designed to withstand any anticipated differential settlement within the footprint. Such structures could then be located anywhere that overall tilt would not be considered excessive. Structures of this type would include detached single family homes with stiffened slabs.

2) Areas with special soil conditions which would result in fairly uniform settlements within a buildings footprint. Such conditions could include areas where very uniform soil conditions would result in uniform settlements, or locations where old dock height fills or existing piles would limit settlements. These areas can be expected to be fairly small and best suited for buildings with small footprints.

The actual locations where such conditions may apply is dependent on a highly complex set of conditions and cannot be accurately determined without detailed site investigations and a better understanding of the planned structures. While these conditions may occur anywhere within the housing study area, we recommend that, for planning purposes, such conditions should not be expected in areas where anticipated areal settlements due to existing areal fills exceed 6 inches for the next 30 years.

BACKGROUND STUDIES

In order to properly address the questions posed by EDAW, a number of background studies were performed. These studies are discussed in the following sections.

Boring Log Data Base

Dames & Moore's data base for boring log information in the Mission Bay area was edited to adjust some of the data to better reflect the recently obtained actual ground surface elevations, to correct a few data entry errors, and to add additional boring information that was not contained in the original study.

Historic Settlement Records

As an important addition to the Mission Bay geotechnical data base, records of approximately 400 periodic surveys of 36 street intersections were obtained from the City of San Francisco's Division of Surveys and Mapping. Each of these records contained elevation measurements for a number of bench marks surveyed on a given date. We collated and reduced this information into a usable time versus measured settlements for 29 intersections. The data spanned the time period from 1918 to 1986. Settlements ranging from 0 to as great as 26 inches were measured for various benchmarks. Estimates of maximum settlements for the last 30 years were made and are presented on Plate 3. These amounts varied from one-half to sixteen inches within the housing area. Representative settlement histories are presented on Plates 6A through 6C.

Revised Contours

The computer program used in our 1982 study to generate contours of the depth to base of recent bay mud, thickness of recent bay mud, and depth to bedrock was re-run on the modified and updated data base. As before, the resulting contours were smoothed and slightly modified to reflect known geologic trends. The results of the historical settlements study described above were also used to guide the interpretations. The contours generated were extended to cover the expanded housing study area and were replotted over a more accurate street map (see Plates 4A, 4B and 5). Some slight differences can be noted when comparing the new contours with those presented in our December, 1982 report, but the general trend and pattern remains the same.

Pile Length Estimates

The estimates for pile lengths presented on Plate 5 of our December, 1982 report were revised based on the modified contours and extended to cover the housing study area (Plate 2).

Areal Settlement Projections

Based on the contour maps created, and projections of the time-settlement curves for the various intersections, an estimate was made of those areas within the housing study region in which 2 to 6 inches of settlement may be anticipated during the next thirty years. The dividing line for less than 2 inches of settlement shown on Plate 1 generally follows the 30' mud thickness contour (see Plate 4B), with some deviations for areas of lesser fill thickness or to reflect historic settlement data. The dividing line for 6 or more inches of settlement is less easily determined, and was assumed to follow the -100 foot bottom of bay mud contour (as discussed in our December 1982 report). It should be noted that these are only general estimates and that local conditions may cause some of those areas marked as settling less than 2 inches to settle more. Similarly, there may be places in those areas designated as settling more than 2 inches to settle much less.

REFERENCES

Dames & Moore, "Geotechnical Consultation, Mission Bay Project, San Francisco, California", December 1, 1982.

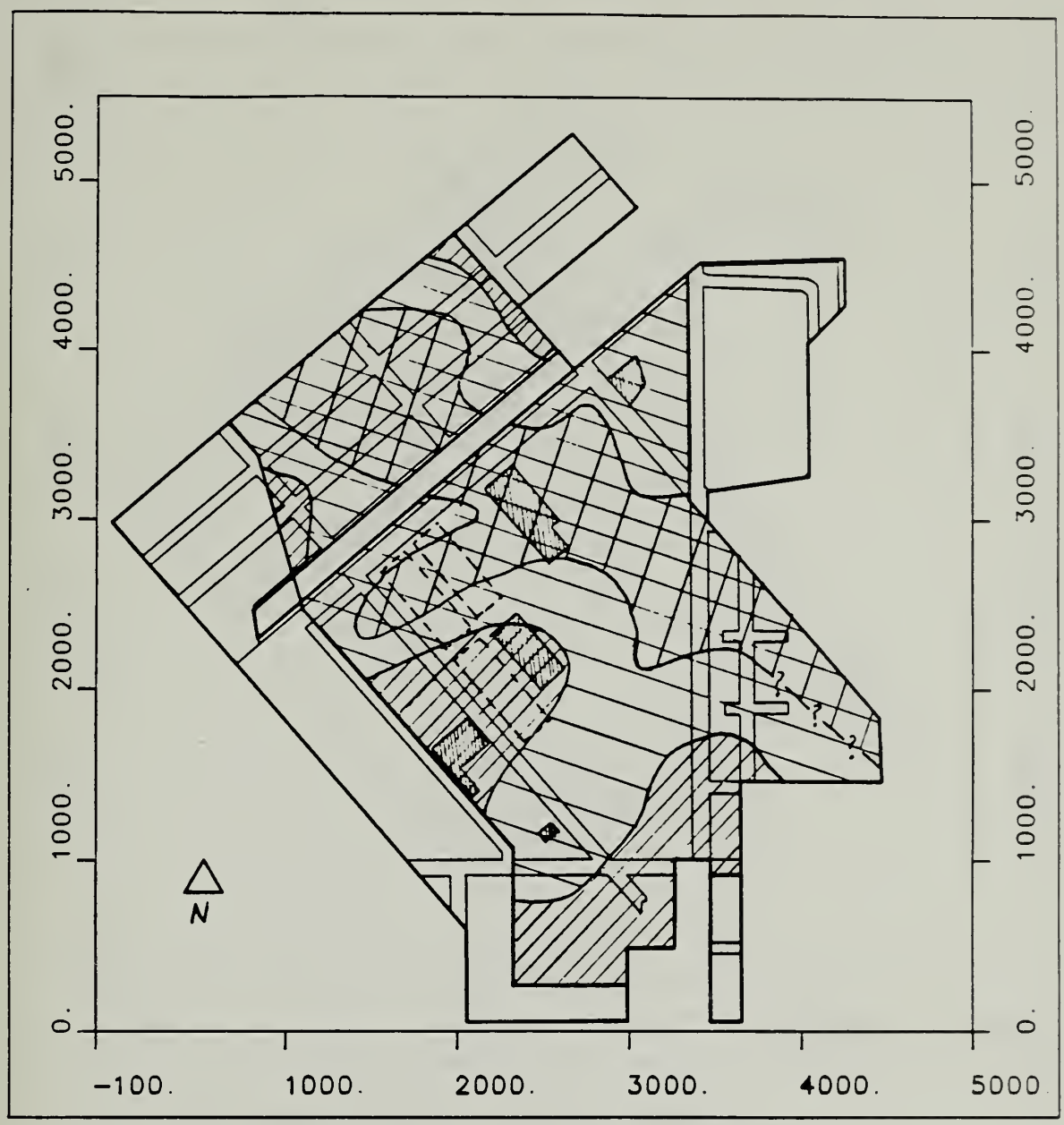
Dames & Moore, "Review of Proposed Land Use Program and Illustrative Plans, February 7, 1986 Working Paper", January 22, 1986.

Dames & Moore, "Preliminary Study of Drainage Wicks vs. Pile Foundations at Mission Bay", April 29, 1986.

San Francisco Department of City Planning, "Draft - Choices for Mission Bay, Planning Considerations", June 11, 1986.

KCA Engineers Inc, "Topographic Map, Mission Bay", undated.

Spiegel and Zamecnik Inc., "Report on Structural Systems for Buildings of Varying Heights and Foundation Conditions - With Costs," September 2, 1983.



HOUSING STUDY AREA

LESS THAN 2" EXPECTED SETTLEMENT OF EXISTING FILLS IN NEXT 30 YEARS

2" TO 6" EXPECTED SETTLEMENT OF EXISTING FILLS IN NEXT 30 YEARS

GREATER THAN 6" EXPECTED SETTLEMENT OF EXISTING FILLS IN NEXT 30 YEARS

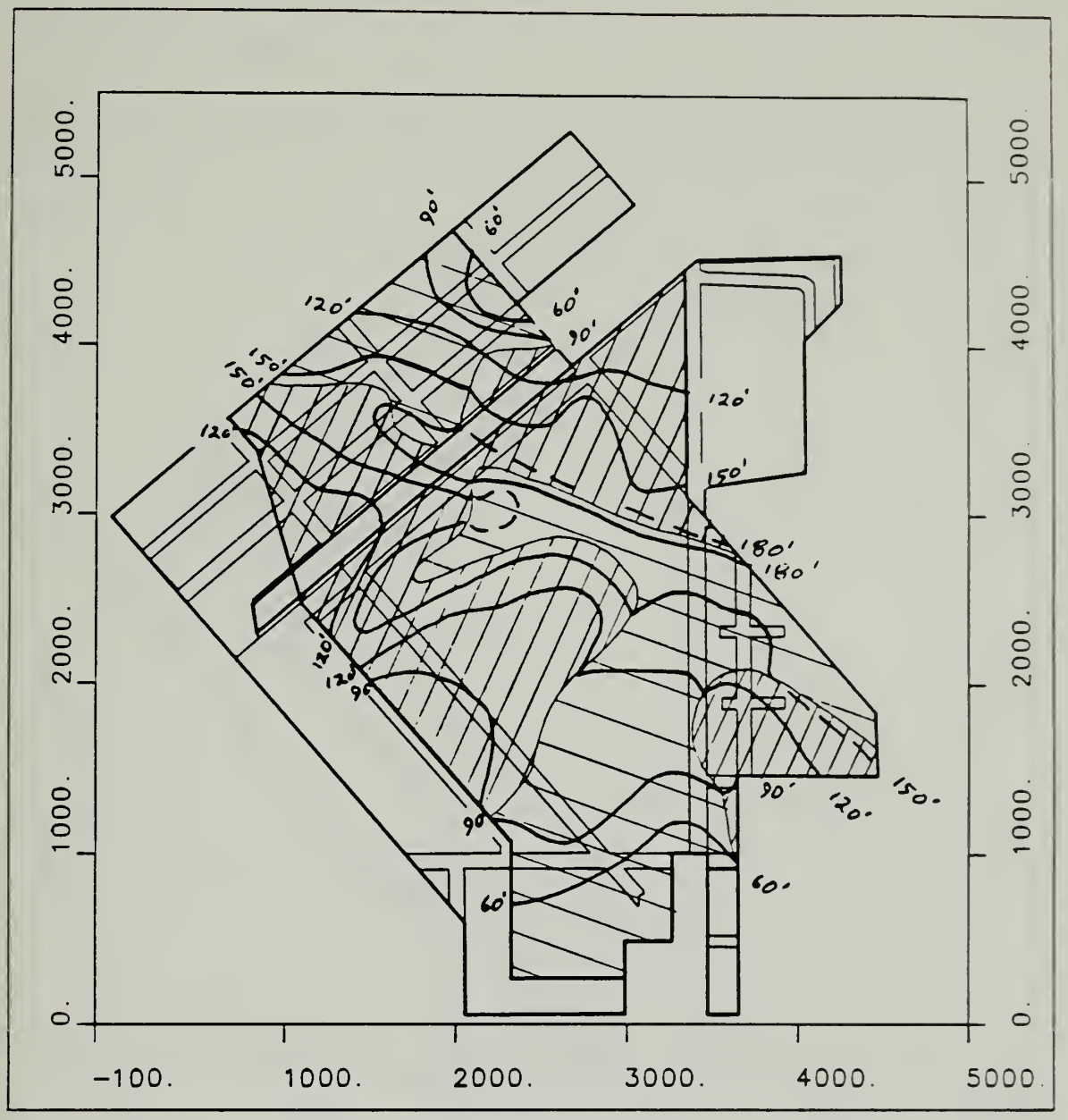
EXISTING OR RAZED PILE SUPORTED STRUCTURE

EXISTING DOCK HEIGHT FILL

GENERALIZED SITE CONDITIONS

Dames & Moore

PLATE 1



CONTOURS DASHED WHERE PROJECTED

BEARING PILES

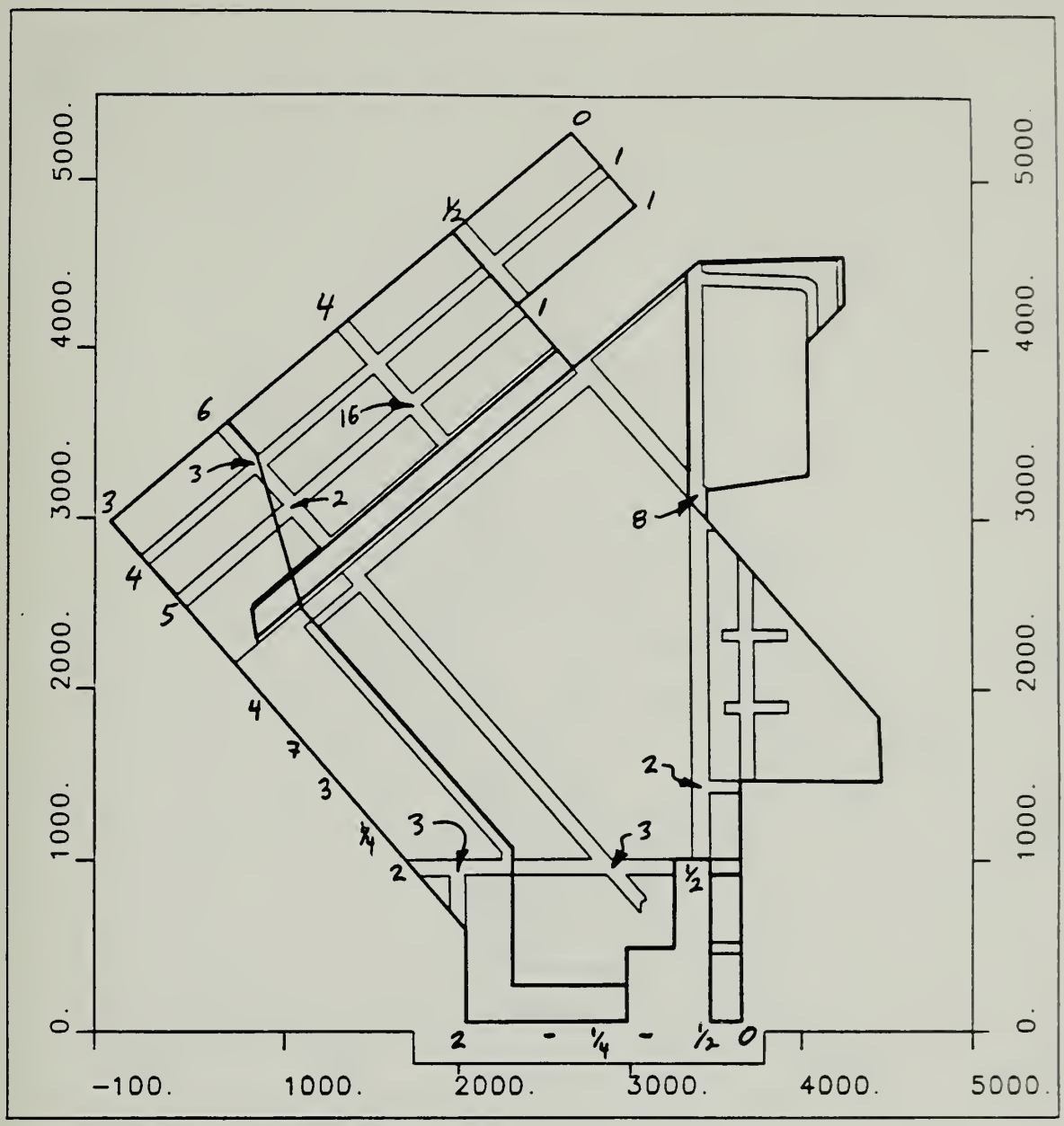
FRICTION PILES

PILE LENGTHS

Dames & Moore

PLATE 2

CHECKED BY _____ FILE _____ BY _____ DATE _____

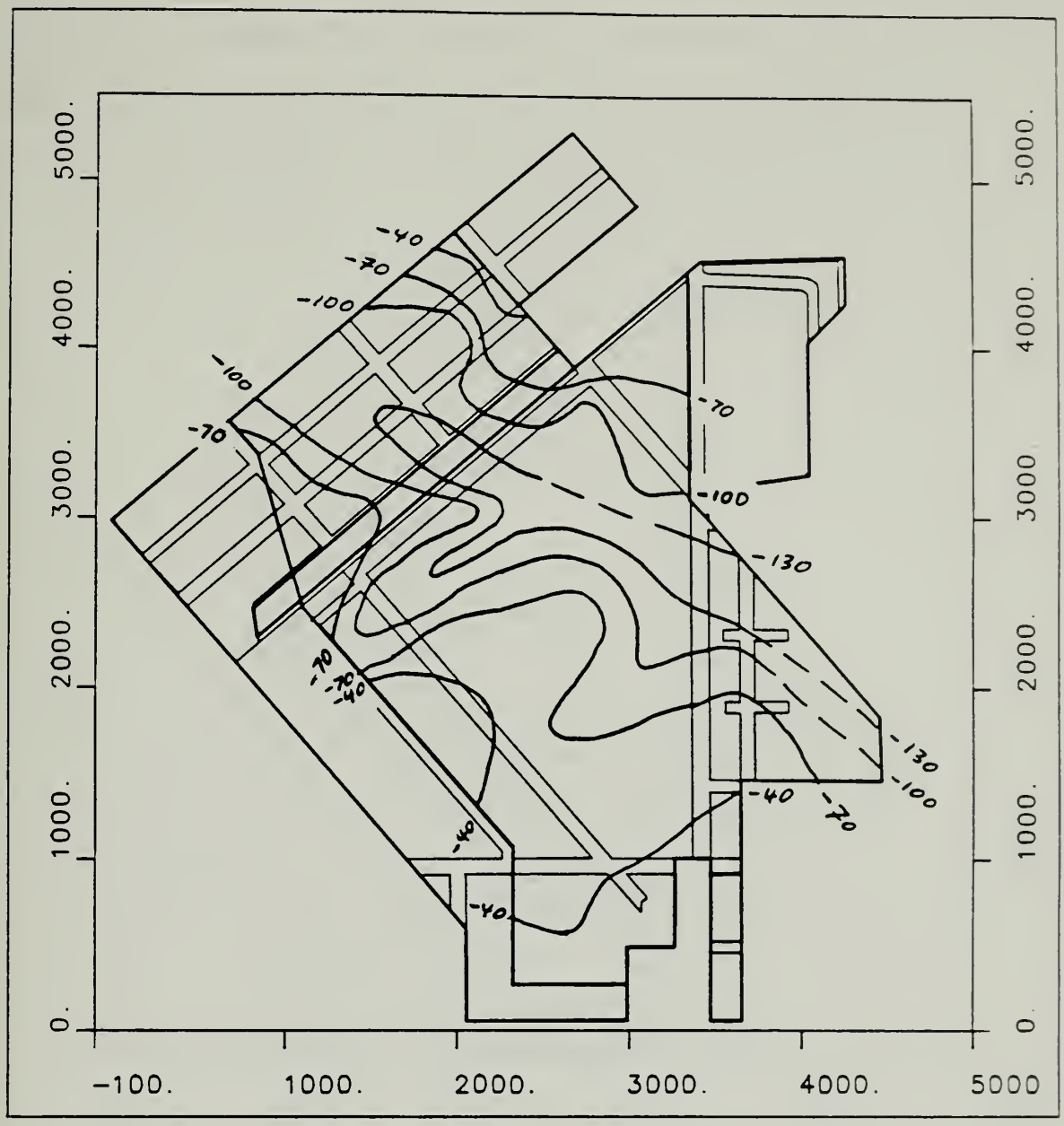


SETTLEMENTS ARE IN INCHES AND ARE BASED ON CITY SURVEY RECORDS

ESTIMATED SETTLEMENTS FOR THE LAST 30 YEARS IN AND AROUND THE MISSION BAY STUDY AREA

Dames & Moore

PLATE 3



S.F. CITY DATUM

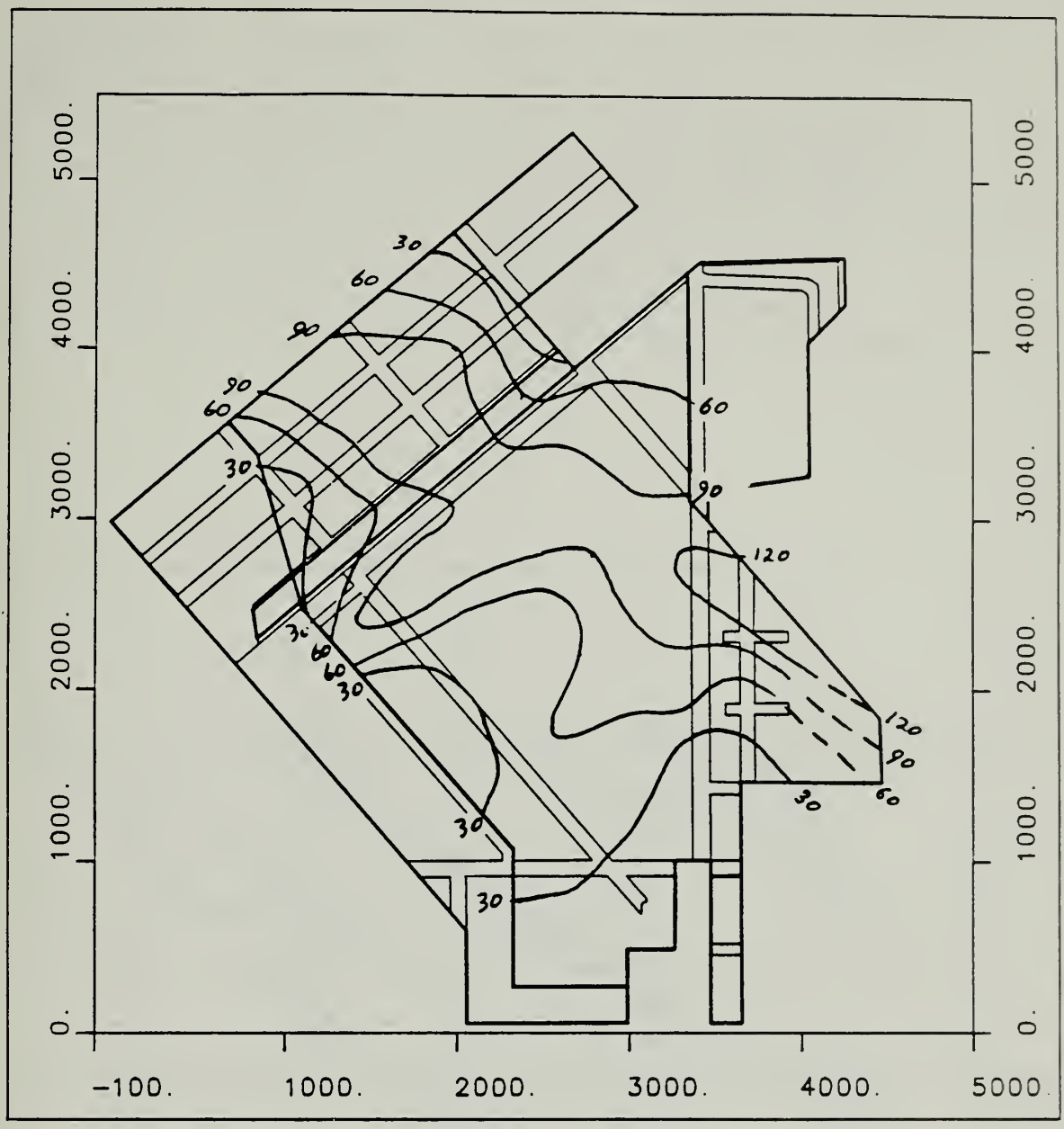
DASHED WHERE PROJECTED

BOTTOM OF BAY MUD

Dames & Moore

PLATE 4A

CHECKED BY _____ FILE _____ BY _____ DATE _____



S.F. CITY DATUM

DASHED WHERE PROJECTED

THICKNESS OF BAY MUD

Dames & Moore

PLATE 4B

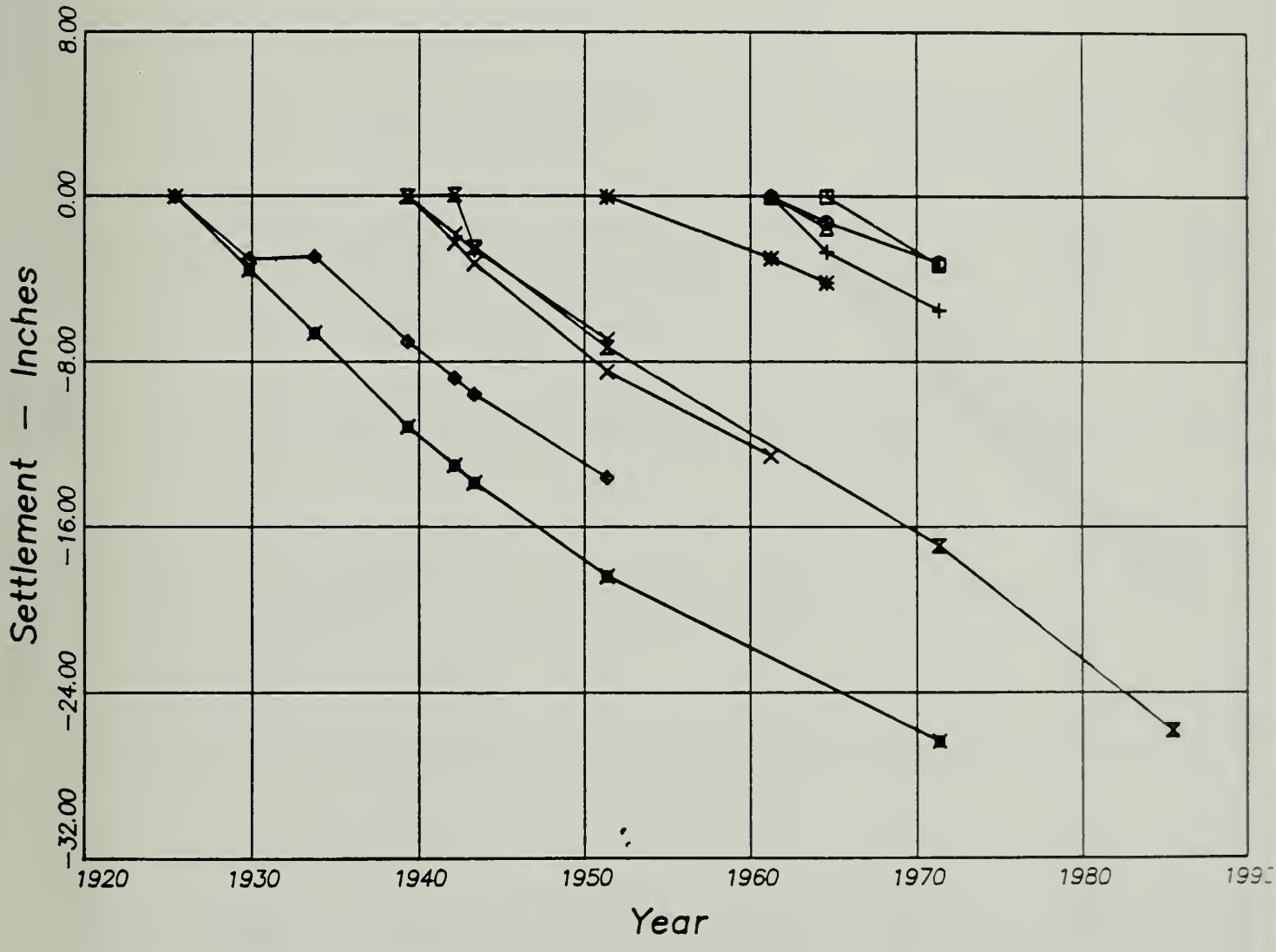
BY _____ DATE _____

FILE _____

CHECKED BY _____

KEY

1 N.W. Fifth St. 40'N + cut S.E. corner conc. platform
2 S.W. Fifth St. + cut outer rim SWI
3 S.W. Fifth St. 3 cuts lower stopcock fire hyd.
4 S.E. Fifth St. 40'S + cut conc landing to steps
5 N.W. Fifth St. + cut S.E. corner conc. landing
6 N.W. Fifth St. 15'W + cut conc. floor E side of Freight door
7 C.C. Fifth St. + cut N. rim M.H.
8 C.C. Fifth St. 30'W + cut N. rim M.H.
9 N.W. Fifth St. + cut N.E. Star iron cess
10 N.E. Fifth St. Letter "O" in OPEN top HPFS Hyd.



Intersection of Berry Street and Fifth Street

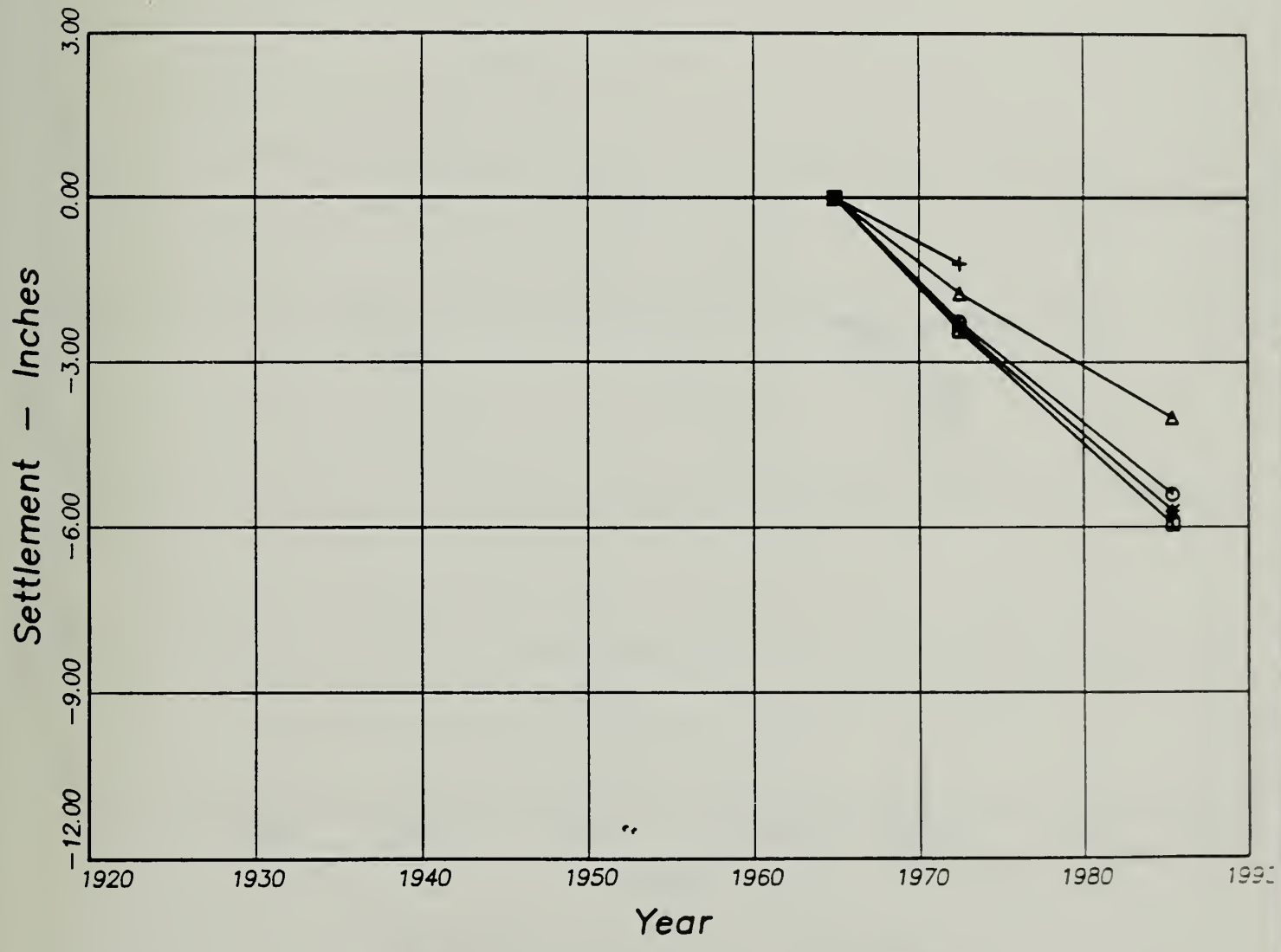
Mission Bay Historical Survey Data

June 30, 1986

PLATE 6A

KEY

1 S.E. 4th St. ^ cut S. side entrance to fire house
2 S.E. 4th St. 30'E cut ASW W end door fire house
3 S.E. 4th St. 3'E USC&G brass disc set in brick N. face. (etc)
4 S.E. 4th St. 90'N nail in lead plug N.W. N'ly corner island
5 C/L 4th St. & W'ly of 3rd st. nail in lead plug E. end of center island



Intersection of Third Street and Fourth Street

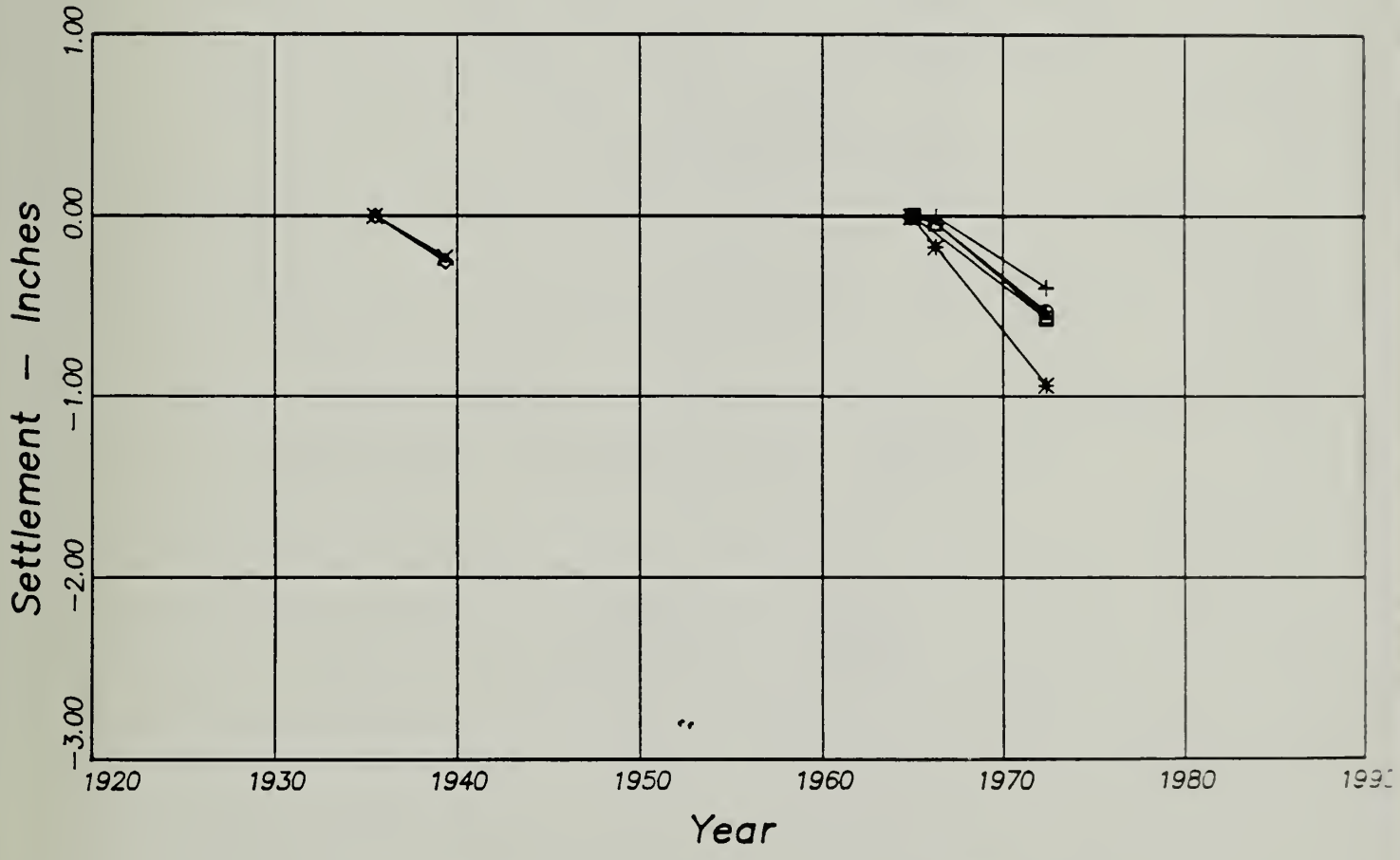
Mission Bay Historical Survey Data

June 30, 1986

PLATE 6B

KEY

1 N.W. 16th St. + cut conc. cess
2 N.E. 16th St. + cut conc. cess
3 S.W. 16th St. 70'W + cut conc. cess
4 S.W. 16th St. 40'W 3 cuts lower stopcock fire Hyd.
5 S.W. 16th St. 45'W & 15'N + cut N. rim Bell Sys. M.H.
7 N.E. 16th St. & 16th St. CLSP Bridge & 15'W of spur Track; 3 cuts in S brace
8 N.E. 16th St. & 16th, @E. curb line of 6th St. & n PL of 16th ST. 3 cuts in .

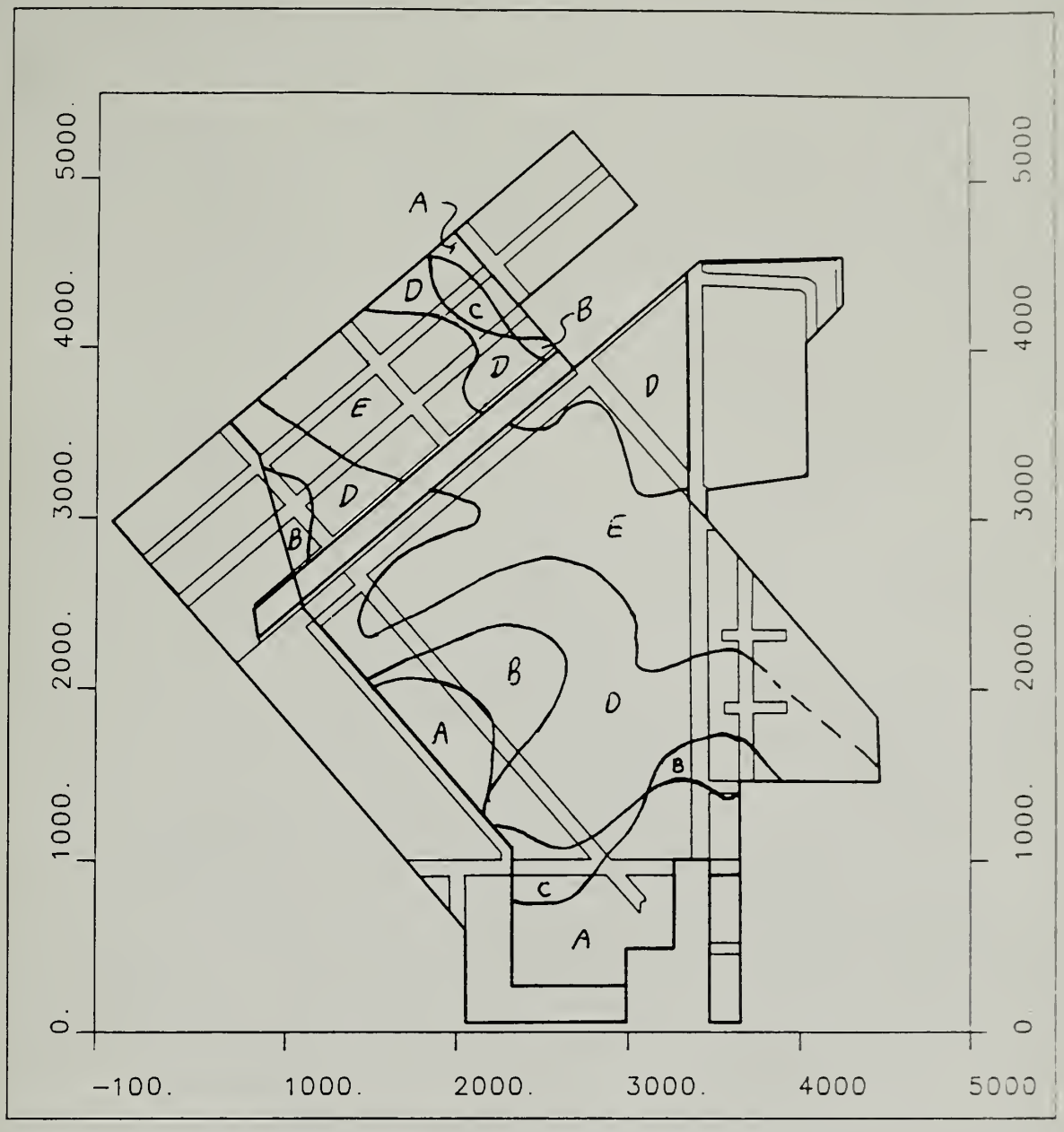


Intersection of 16th Street and Sixth Street

Mission Bay Historical Survey Data

June 30, 1986

PLATE 6 C



BOUNDARIES DASHED WHERE PROJECTED

Zone	Anticipated Areal Settlement (inches)	Estimated Pile Lengths (feet)
A	< 2	< 90
B	< 2	90 - 150
C	2-6	< 90
D	2-6	90 - 150
E	> 6	> 100

GENERALIZED SOIL ZONES

Dames & Moore

PLATE 7

CHECKED BY _____ FILE _____ BY _____ DATE _____ REVISIONS